Chapter 2 Ecological Conditions and Trends

Introduction

Chapter 1 described the Chugach National Forest planning area and the three different geographic areas of the national forest. This chapter describes the overall ecological integrity of the area. Ecological integrity for this assessment is defined as:

> *"The quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence." (36 CFR 219.19)*

The ecosystems described in this chapter include terrestrial (soils, vegetation, and wildlife), aquatic (freshwater and coastal marine ecology) and the interface between the two (riparian areas and wetlands).These ecosystems are evaluated at the forestwide and geographic area scales where appropriate. Key characteristics of each ecosystem are identified, including species composition and diversity, structure, function, and connectivity. Existing conditions and trends of the key characteristics are described for each ecosystem. System drivers are also discussed and include dominant ecological processes, disturbance regimes, and stressors for the different ecosystems.

This chapter also includes a discussion of federally recognized threatened, endangered, proposed, and candidate species that occur within the Chugach National Forest and a discussion of potential species of conservation concern. It concludes with a discussion and summary findings of the ability of the aquatic, terrestrial, and riparian ecosystems in the plan area to adapt to a rapidly changing climate.

Physical properties of the environment both constrain and enable the development of some ecological systems within the Chugach National Forest. A brief overview of the physical properties of the Chugach National Forest environment follows. Those that most directly influence ecosystems are emphasized.

The Chugach National Forest includes the northernmost coastal temperate rain forests in North America and areas transitional to boreal forests. It is almost entirely within the Kenai-Chugach mountain system. The Kenai-Chugach mountain system is a topographically continuous mountain chain that extends from Kodiak Island through the Kenai Peninsula and around Prince William Sound, eventually connecting to the Saint Elias Range to the east. The principle fault systems in the area follow the same curved trend as the Kenai-Chugach mountain system. The Border Ranges fault lies in the lowlands along the mountain front and nearly parallels the western border of the Chugach National Forest (Karl, Vaughn, & Ryherd, 1997 Guide to geology of the Kenai Peninsula, Alaska, 1997).

Rock type and geologic processes work together to affect the surficial geology of the Chugach National Forest. Ecological and physical dynamics of the national forest are strongly influenced by snow and ice. Glaciers, in conjunction with both tectonic forces and the erosion from rivers, are responsible for carving the topographic relief of the national forest and associated marine environment. Topography in turn affects environmental elements, such as slope, soil types, weather, drainage patterns, and vegetation types. Past episodes of glacial scouring and tectonic activity result in a legacy of disturbance apparent in regionwide patterns of directional change in topography and ecology. In addition to the long-term effects of glaciers and icefields, annual snow accumulation has an impact on vegetation, streamflow and chemistry, stream morphology, fish, wildlife, recreation opportunities, and a myriad of other things.

Aquatic Ecosystems—Watersheds

This section describes the watershed component of the aquatic ecosystems evaluation. Specific items evaluated include key ecosystem characteristics by geographic area, such as water quantity and water quality, drivers and stressors, and watershed condition and trends. This section also provides a summary of the overall watershed conditions across the national forest based on the national Watershed Condition Framework (WCF) and the Forest Service Watershed Condition Classification (WCC) Technical Guide (Potyondy & Geier, 2010) and an evaluation of watershed integrity.

Relevant Information

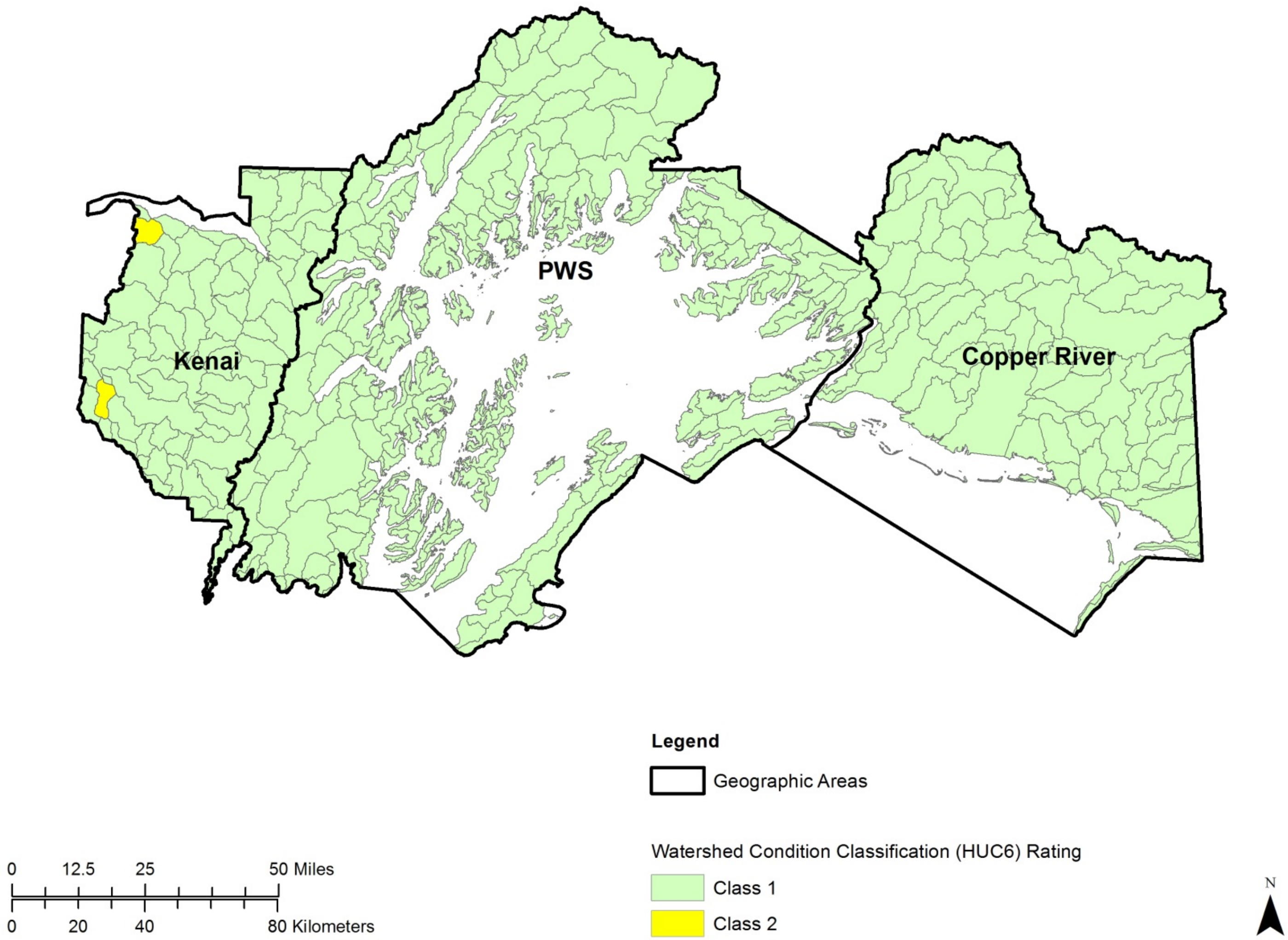
- Watersheds within the Chugach National Forest generally are in good condition, are functioning properly, and have good water quality. Natural processes, such as glaciers, mass wasting, and natural bank erosion, remain the primary sources of sediment loads and turbidity in streams and rivers across the national forest. Human associated water quality concerns exist in limited locations primarily in heavily visited areas close to roads and in developed areas. The following localized water quality concerns exist: erosion, sedimentation, and/or wetland damage from off-highway vehicles (OHVs) on authorized and unauthorized routes; sedimentation and pollutants associated with backcountry motor vehicle use; fecal coliform pollution from recreation related human waste; sedimentation from mining activities; and sedimentation from roads, trails, and recreational activities.
- A number of watershed improvement projects have occurred within the national forest since 2002. These projects have improved the function of streams and riparian areas impacted by past or historic land management activities.
- Changes in watershed characteristics, such as surface and groundwater quantity, quality, and flow regimes as well as erosion and deposition of sediments are occurring across the national forest.
- The primary system driver to Chugach National Forest watersheds is climate change with additional limited and localized stressors of spruce bark beetle infestation, increased invasive aquatic organism and plant infestations, and increased population and/or national forest use.

Ecosystems Evaluated

Watersheds are useful units to delineate aquatic and terrestrial ecosystems. A watershed is the area of a landscape where water from rain or melting snow and ice drains downhill into a body of water, such as a river, lake, reservoir, or ocean. Watersheds include streams and lakes and shallow aquifers, as well as the land surfaces from which water drains. Topography and geology determine where the water flows along with the boundary of each watershed. Small watersheds drain into progressively larger ones, creating a hierarchical structure, or watersheds levels. These watershed delineation levels are based on hydrologic unit codes (HUCs). The Chugach National Forest has 275 6th-level HUC (HUC 6) watersheds that range from 8,000 to more than 300,000 acres spread across the three geographic areas (see table 2 and map 2). Prince William Sound holds nearly half of these. Three watersheds span two geographic areas. Within the Chugach National Forest, most are standard watersheds with a drainage flowing to a single outlet point. Prince William Sound is the exception where the majority of the HUC watersheds are frontal and include several small drainages with more than one outlet along the coastline of the ocean. More than half of Chugach National Forest watersheds have had no modification to natural overland flow and a little more than 40 percent have some glacial component.

Table 2. Number of HUC 6 watersheds for the three different geographic areas

Geographic Area	HUC 6 Watersheds
Both the Copper River Delta and Prince William Sound	3
Copper River Delta	72
Kenai Peninsula	67
Prince William Sound	133
Total	**275**



Map 2. Chugach National Forest Service delineated HUC 6 watersheds by geographic areas and the results of the WCC rating (adapted from (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)).

Each Chugach National Forest watershed is a network of stream channels that differ in character and are referred to as channel types. Channel types across the national forest vary with landscape and topography and are characterized in the Alaska Region by stream process groups (USDA 2010). These stream process groups are based on primary differences in hydrologic function, landform, and channel morphology and include: estuarine (ES), palustrine (PA), glacial outwash (GO), flood plain (FP), low gradient contained (LC), moderate gradient contained (MC), alluvial fans (AF) and high gradient contained (HC) (see figure 1). Figure 2 displays the lengths and distribution of the different channel type process groups across the geographic areas. Overall, Prince William Sound has the most stream miles, followed by the Copper River Delta and then the Kenai Peninsula. The Copper River Delta has the highest percentage of GO, PA, and ES channel types with the Kenai Peninsula having very minimal ES channels due to its more interior and mountainous topography. Prince William Sound and Kenai Peninsula tend to be dominated more by HC channel types, followed by GO and then some of the more moderate gradient channel types (MM and MC). Individual channel type classification units within each process group are defined by physical attributes, such as channel width and/or incision depth, gradient, and channel pattern.

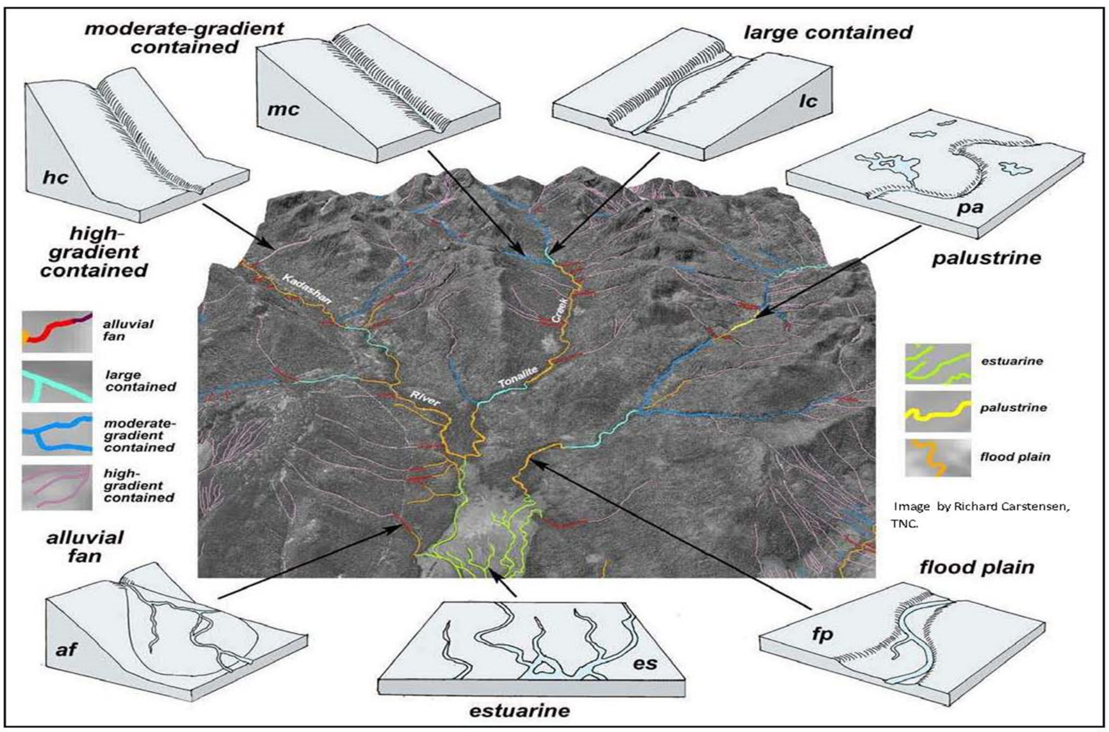


Figure 1. The Alaska Region channel type process groups displayed across the typical landscape (USDA, 2010b).

Figure 2. The lengths and distributions of the Alaska Region channel type process groups across the three geographic areas of the Chugach National Forest. See text for abbreviations.

Key Ecosystem Characteristics

Watershed condition is the state of the physical and biological characteristics and processes within a watershed that affect the hydrologic and soil functions supporting aquatic and terrestrial ecosystems. The basic model used in the WCF provides a systematic, flexible means of classifying and comparing watersheds based on a core set of national watershed condition indicators. These indicators are grouped according to four major process categories:

1. Aquatic physical
2. Aquatic biological
3. Terrestrial physical
4. Terrestrial biological

Each of these four process categories was evaluated using a set of attributes (see table 3). All of these attributes and qualities contribute to the health of the watershed ecosystem.

The Forest Service classified conditions for 275 HUC 6 watersheds using the process outlined in the WCC. The categories displayed in table 4 represent ecosystem processes or mechanisms by which management actions can affect the condition of watersheds and associated resources. Chugach National Forest watersheds were classified by each attribute into one of the three condition classes: Class 1 (good, functioning properly); Class 2 (fair, functioning at risk); or Class 3 (poor, functionally impaired) using data from internal sources: landscape assessments, watershed restoration plans, hydrologic assessments, culvert surveys, and fire regime maps along with data from external sources: Alaska Department of Environmental Conservation (ADEC) and Alaska Department of Fish and Game (ADF&G). In the end, the ratings for each attribute were summed to give an overall general condition of each watershed.

This section provides details of the water quality and water quantity indicator and attributes of the aquatic physical processes. Please refer to the Aquatic Ecosystems—Fish section for more detailed information about the aquatic biota and aquatic habitat indicators and the Aquatic Ecosystems—Riparian and Wetlands section for more detailed information about the riparian vegetation indicator of the Aquatic Biological Process Category. More detailed information about the terrestrial, physical, and biological processes are described in the Terrestrial Ecosystems sections. Overall Chugach National Forest watershed conditions, based on all of the table 3 core indicators and attributes, are also included.

Table 3. Core national watershed condition indicators and attributes (Potyondy & Geier, 2010)

Process Category	Indicator	Attribute
Aquatic physical	Water quality	Impaired waters
		Water quality problems
	Water quantity	Flow characteristics
	Aquatic habitat	Habitat fragmentation
		Large woody debris
		Channel shape and function
Aquatic biological	Aquatic biota	Life form presence
		Native species
		Exotic and/or aquatic invasive species
	Riparian vegetation	Vegetation condition
Terrestrial physical	Roads and trails	Open road density
		Road and trail maintenance
		Proximity to water
		Mass wasting
	Soils	Soil productivity
		Soil erosion
		Soil contamination
Terrestrial biological	Fire regime	Fire regime condition
	Forest cover	Forest cover condition
	Rangeland vegetation	Rangeland vegetation condition
	Terrestrial invasive species	Terrestrial invasive species condition
	Forest health	Insects and disease
		Ozone

Water Quantity

Watershed condition plays a large role in the magnitude, frequency, and timing of runoff from a watershed. The quantity and timing of streamflow are critical components of water supply, water quality, and the ecological integrity of watersheds. Modifying natural flow regimes and hydrologic processes disrupts the equilibrium between the movement of water and the movement of sediment thereby altering physical habitat characteristics, including water temperature, oxygen content, water chemistry, and substrate composition, and adversely changing the structure or function of aquatic, riparian, and wetland ecosystems.

The Chugach National Forest has an abundant water supply resulting from the heavy precipitation it receives. Water quantity can be subdivided into surface water and groundwater. Surface water is a function of the water flowing into a drainage in the form of precipitation minus the water leaving the system through evaporation, transpiration, and groundwater transport. Groundwater is by definition water that occurs in the zone of saturation below the earth's surface.

Surface water

Approximately 9,500 miles of perennial stream channels, which includes a line that extends from the head to the mouth of each lake, flow through the national forest. Hundreds of streams flow directly into the

Pacific Ocean, and most of these streams are home to fish species. Chugach National Forest watersheds vary in size from the 24,000 square mile Copper River Basin and the 2,200 square mile Kenai River Basin down to small first order drainages. For some of these drainages, only portions are within the national forest boundary. Surface waters within the Chugach National Forest originate as runoff from snowmelt, rainfall, and glacial melt, yielding approximately 40 million acre-feet of water per year from National Forest System lands. Snowfall is generally the greatest contributor to total runoff, while intense rainfall events and rare glacial outburst floods usually cause the largest floods. The majority of the watersheds within the national forest have some component of glacial drainage. Glaciers within the Chugach National Forest, though still very much present, have been diminishing, releasing stored water as they melt. As glacial retreat continues, the amount of glacial melt diminishes. These glacial contributions provide varying benefits, such as freshwater sources to salt water ecosystems and enhanced flows during warm, low precipitation periods.

Surface water is affected by both the character of its watershed and by precipitation patterns. Chugach National Forest watersheds show a large variety of drainage and flow characteristics. In general, Prince William Sound receives the greatest amount of precipitation and has the most stream flow per square mile while the Kenai Peninsula has the least. May through October is the major runoff season within the Chugach National Forest, with generally more than 80 percent of annual runoff occurring during these six months.

Flows peak rapidly in the shorter, steep gradient, coastal streams in Prince William Sound during heavy rain storms and decrease sharply during dry spells. Highest flows in these watersheds are generally during the period of heaviest rainfall, or August through November.

Inland streams often have highest flows during snowmelt runoff in May, June, and July. They are less likely to have sharp rainfall related flow peaks than coastal streams since they receive lower rainfall intensities. Many Chugach National Forest streams have characteristics of both coastal and inland streams, with both June snowmelt peaks and autumn rainfall peaks.

Glacial dominated watersheds have a somewhat different hydrograph. The major runoff from glaciers occurs during mid-summer melt (late-June through August) when air temperatures and solar radiation intensities are highest. Overall, the largest flood peaks generally occur on major rainfall events in the late summer and early fall. The lowest flows generally occur during the February through early April timeframe (Blanchet, 1983).

Hyporheic zones are the loosely defined functional, ecological, and geophysical zones between aquatic and terrestrial systems and between surface water and groundwater. These areas are indicators of proper ecological function and are acknowledged as being very important to water quality, biological diversity, and nutrient recycling (Hancock, Boulton, & Humphreys, 2005). Recent research indicates the organisms in hyporheic zones function in the breakdown of pollutants.

Of particular interest to the Chugach National Forest, the hyporheic zone includes the underground transition between saline and freshwater systems and the biologic communities they support. Healthy hyporheic zones can respond to tidal surges that commonly occur along coastal areas (Williams, 2003).

Gravel extraction, soil compaction, dams, alteration of flooding regimes, and silt load runoff are a few of the impacts that can damage the function of hyporheic zones (Hancock, 2002).

Groundwater

Rainfall and snowmelt also recharge groundwater sources within the national forest. Groundwater flow occurs primarily as localized flow controlled by the permeability of aquifer materials and surface topography. Alluvium of river valleys, glaciofluvial deposits, and the coastal lowlands make up the most productive aquifers within the Chugach National Forest. Recharge and discharge rates from these groundwater aquifers are dependent on porosity and permeability, local precipitation, and time of year. Snow will not recharge the groundwater system until it begins to melt in the spring or during winter warm spells. Groundwater aquifers release water during periods of low precipitation to maintain base flows of streams. In some cases, groundwater seeps and springs are vitally important to providing habitat for over-wintering salmon eggs and fry and some invertebrates. Groundwater dominated systems may provide more moderated flows, bed movement, water temperatures, and sediment loads preferable for salmon spawning and rearing habitat.

Water quantity drivers and stressors

Water quantity condition was evaluated as part of the WCC effort. Water quantity condition addresses changes to the natural flow regime with respect to the magnitude, duration, or timing of natural streamflow hydrographs. The water quantity attribute indicator was evaluated based on the condition rating rule set displayed in table 4.

Disturbance regimes to water quantity include human influences, such as reservoirs, diversions, and withdrawals. Other influences on water quantity include fires, spruce bark beetle infestations, and climate change. Based on parameters outlined in the WCC, these influences were not included in this analysis; however, it is important to note them as drivers and stressors. The water quantity attribute in the WCC was analyzed qualitatively based on general knowledge of existing stream diversions and their effects on water resources using the guidelines in the technical guide (Potyondy & Geier, 2010). This analysis did not include hydropower projects that are in the planning stage (e.g., Grant Lake) or impacts that occur outside the national forest boundary (e.g., Humpback Creek near Cordova) or in areas upstream from National Forest System lands (e.g., water rights and uses in the Copper River Basin).

Table 4. Water quantity condition rating rule set (Potyondy & Geier, 2010)

Attribute	Water Quantity Condition Indicator		
	Class 1 (good, functioning properly)	**Class 2 (fair, functioning at risk)**	**Class 3 (poor, functionally impaired)**
Flow characteristics	The watershed lacks significant man-made reservoirs, dams, or diversion facilities. The watershed has primarily free-flowing rivers and streams, unmodified lakes, and no or limited groundwater withdrawals. Stream hydrographs have no or minor alterations from natural (unaltered by anthropogenic actions) conditions.	The watershed contains dams and diversion facilities that are operated to partially mimic natural hydrographs. A departure from a natural hydrograph occurs during periods other than extreme flows (lows or highs). Peaks and base flows are maintained but changes to the timing, rate of changes to the timing, rate of change, and/or duration of mid-range discharges occur.	Dams and diversion facilities are operated so that they fail to mimic natural hydrographs. The magnitude, duration, and/or timing of annual extreme flows (low or high) significantly depart from the natural hydrograph. The timing and rate of change in flows often do not correlate with expected seasonal changes.

Water quantity condition and trends

Most Chugach National Forest watersheds have no human impacts to water quantity in terms of diversions or reservoirs, and stream hydrographs are generally unaltered by human actions. Exceptions to this occur in a few localized areas near communities and along the road system. The results of the WCC rating for water quantity within the Chugach National Forest are displayed in tables 5 and 6 and map 3.

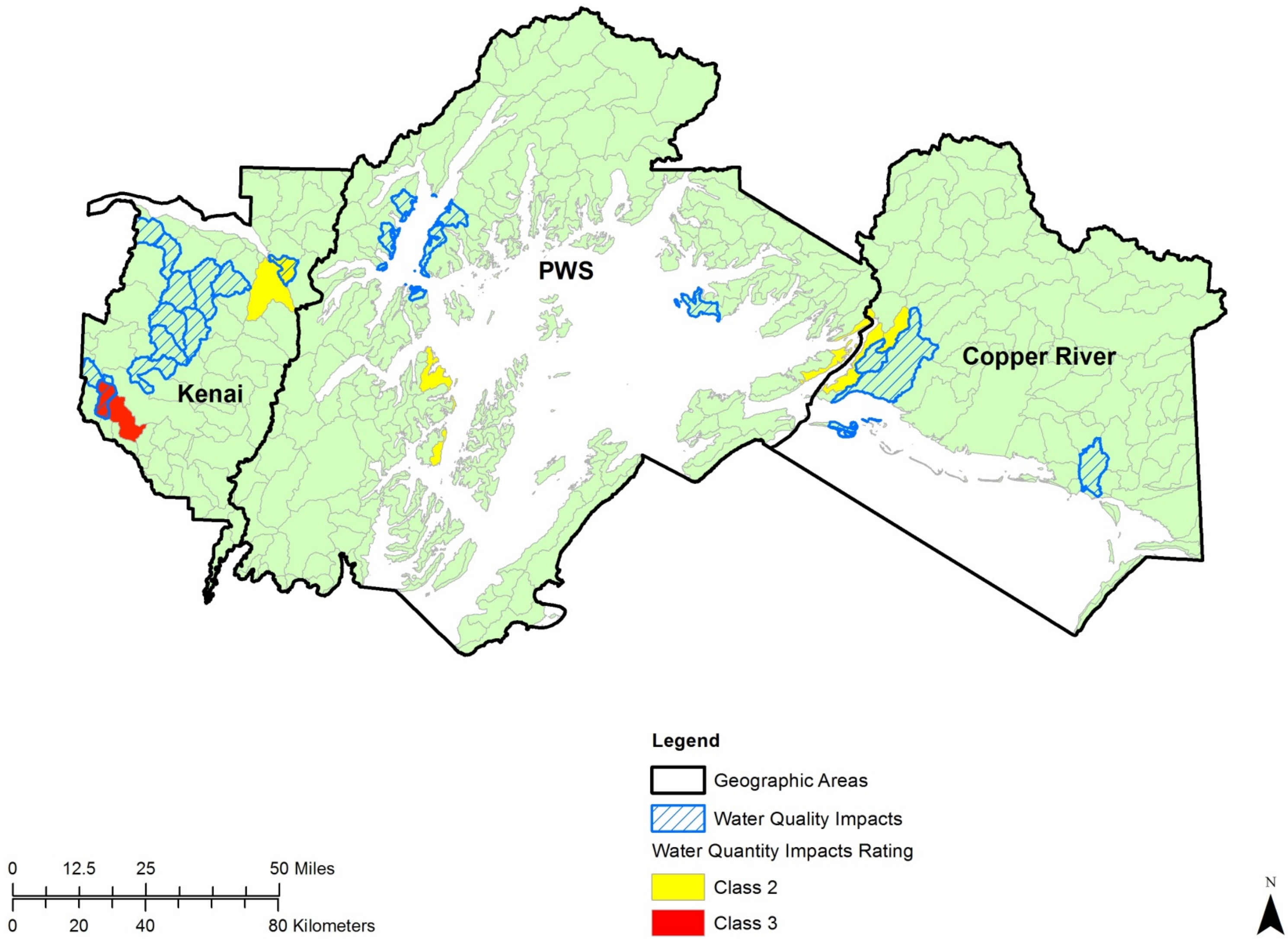
Though it was not included in this list, it is worth mentioning that water is diverted from Resurrection Creek for washplants for placer mining activities during the summer months.

Table 5. Results of the WCC water quantity condition ratings for the Chugach National Forest (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Rating	Watersheds
Class 1 (good, functioning properly)	268
Class 2 (fair, functioning at risk)	5
Class 3 (poor, functionally impaired)	2

Table 6. Watersheds within the Chugach National Forest that exhibit deviations from their natural hydrograph (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Geographic Area	HUC	Watershed Name	Rating	Comments
Copper River Delta	190201041603	Power Creek	2	Run of the river dam de-waters a portion of Power Creek for hydroelectric power generation.
	190202010200	Orca Inlet-Frontal Prince William Sound	2	Heney Creek is municipal watershed for Cordova, with water diverted into Meals Reservoir.
Kenai Peninsula	190203020304	Portage Creek	2	Explorer Creek diverted into Placer River Watershed by Portage Glacier Highway. Flow alteration caused by gravel extraction ponds.
	190203020305	Skookum Creek-Placer River	2	Explorer Creek diverted into Placer River Watershed by Portage Glacier Highway, Railroad diverts some drainages and causes artificial concentration of flows along the tracks.
	190203021402	Cooper Lake	3	Cooper Lake is artificial reservoir, artificial controls on lake water surface elevation with large fluctuations.
	190203021403	Stetson Creek-Cooper Creek	3	Cooper Lake Dam completely de-waters a 1.5-mile section of Cooper Creek.
Prince William Sound	190202012510	Falls Lake-Frontal Prince William Sound	2	Main Bay Fish Hatchery diverts water from lake and de-waters stream at head of bay.



Map 3. Chugach National Forest watersheds with water quantity and water quality impacts.

Water quantity within the national forest is primarily affected by water storage, water withdrawals, and climate change. Upstream water right reservations are held on the Copper River. Full utilization of these reservations coupled with effects from climate change may reduce future stream flows and sediment transport capabilities to the Copper River Delta. There are also several proposed (not yet constructed) hydroelectric projects within the national forest. These projects have the potential to or will affect water quantity by diverting and/or impounding water. During the last 10 years, numerous hydroelectric projects within or near the Chugach National Forest have been proposed. The water resources of the national forest are receiving regional, national, and international attention as a potential source for renewable energy. This trend is expected to continue for the foreseeable future. Please refer to the Hydroelectric section in chapter 3 for more detail. Given this trend, it can be anticipated that demands for water from the national forest will increase, which would ultimately affect future water quantity and alter natural flow conditions.

Although not part of the WCC, the impacts of severe wildland fire and beetle kill have had documented effects on the hydrologic regime and hydrograph of watersheds. In general, some of these effects have included increased snow accumulation and melt, reduced interception loss and evaporation, and increased runoff and streamflow (Pugh & Small, 2011; Schnorbus, 2011; Winkler, 2011).

Water Quality

Water quality refers to the chemical, physical, and biological characteristics of water. The quality of water, both surface and groundwater, affects the health of the entire watershed, including all of the components of the aquatic and terrestrial ecosystems. In this section, class refers to a Forest Service designation based on WCC and category refers to a state designation based on the Clean Water Act.

Water quality drivers and stressors

Water quality drivers and stressors within the Chugach National Forest include natural and human caused disturbances. Natural disturbances primarily include climate change, landslides, and floods. Human caused physical, biological, and chemical impacts to water quality were assessed for 275 watersheds within the Chugach National Forest as part of the WCC. Data sources for this analysis included knowledge from local specialists, the Alaska Department of Environmental Conservation 2010 Water Quality Inventory and Assessment Report (ADEC, 2010), the Alaska's DRAFT 2012 Integrated Water Quality Monitoring Assessment Report (ADEC, 2012) and Alaska's FINAL 2012 Integrated Water Quality Monitoring and Assessment Report (ADEC, 2013). The methodology is outlined in the WCC (Potyondy & Geier, 2010).

Water quality function and condition were evaluated based on the following attributes as listed in State of Alaska Department of Environmental Conservation Section 303(d) (of the Clean Water Act): impaired waters and water quality problems not listed as impaired waters. Alaska state water quality standards (WQS) specify a variety of pollutants for fresh and marine uses. Attainment of standards is required for the following: color; fecal coliform bacteria; dissolved oxygen; dissolved inorganic substances; petroleum hydrocarbons, oils, and grease; pH; radioactivity; residues (floating, solids, foam, debris, and deposits); sediment; temperature; toxic substances; and turbidity (ADEC, 2012). Water quality condition was then rated into three classifications: Class 1 (good, functioning properly); Class 2 (fair, functioning at risk); or Class 3 (poor, functionally impaired) (see table 7).

Table 7. Water quality condition rating rule set (Potyondy & Geier, 2010)

Attribute	Water Quality Condition Indicator		
	Class 1 (good, functioning properly)	**Class 2 (fair, functioning at risk)**	**Class 3 (poor, functionally impaired)**
Impaired waters (303(d) listed)	No state-listed impaired or threatened water bodies.	Less than 10 percent of the stream miles or lake area of a watershed is listed on the 303(d) or 305(b) lists and are not supporting beneficial uses.	More than 10 percent of the stream miles or lake area of a watershed are water quality limited and are not fully supporting beneficial uses as identified by the Alaska Department of Environmental Conservation integrated report (303(d) and 305(b)).
Water quality problems (not listed)	The watershed has minor or no water quality problems. For example, no documented evidence of excessive sediment, nutrients, chemical pollution or other water quality issues above natural or background levels; no consumption advisories or contamination from abandoned or active mines; little or no evidence of acidification, toxicity, or eutrophication because of atmospheric deposition.	The watershed has moderate water quality problems. For example, consumption advisories in localized areas; minor contamination from active or abandoned mines; localized incidence of accelerated sediment, nutrients, chemicals, or infrequent, documented incidents of contamination of public drinking water sources. Moderate evidence of acidification, eutrophication, or toxicity because of atmospheric deposition.	The watershed has extensive water quality problems. For example, consumption advisories over extended areas; excessive sediment, nutrients, chemicals; extensive contamination from active or abandoned mines; or frequent incidents of contamination of public drinking water sources. Strong evidence of acidification, eutrophication, or toxicity because of atmospheric deposition.

Watersheds were ranked by impaired waters based on categorical listings from ADEC (ADEC, 2010; ADEC, 2012) as described in the technical guide and displayed in table 7 (Potyondy & Geier, 2010). The state of Alaska assigns categories to water bodies by the degree to which water quality goals are attained. The five categories and three subcategories follow:

- Category 1: All WQS for all designated uses are attained
- Category 2: Some WQS for the designated uses are attained, but data and information to determine whether WQS for the remaining uses are attained is insufficient or absent
- Category 3: Data or information is insufficient to determine whether the WQS for any designated uses are attained
- Category 4: The waterbody is determined to be impaired but does not need a total maximum daily load (TMDL)
    - Category 4a. An established and EPA-approved TMDL exists for the impaired water
    - Category 4b. Requirements from other pollution controls have been identified to meet WQS for the impaired water
    - Category 4c. Failure to meet water quality standards for the impaired water is not caused by a pollutant; instead, the impairment is caused by a source of pollution, such as nuisance aquatic plants, degraded habitat, or a dam that affects flow
- Category 5: WQS for one or more designated uses are not attained and the water body requires a TMDL or recovery plan; Category 5 waters are those waters identified by the Section 303(d) list of impaired waters

Watersheds were ranked and analyzed qualitatively on non-listed water quality problems based on input by resource professionals, knowledge, reports, and professional judgment of conditions in the watersheds using the guidelines in the technical guide (Potyondy & Geier, 2010).

Water quality condition and trends

Overall, water quality, both surface and subsurface, is good within the Chugach National Forest. Natural processes, such as glaciers, mass wasting, and natural bank erosion, remain the primary sources of sediment loads and turbidity in streams and rivers across the national forest. Human associated water quality concerns exist in limited locations primarily in heavily visited areas close to roads and in developed areas.

The results of the condition rating for water quality in the WCC for the Section 303(d) listed impaired waters attribute are displayed in table 8.

Table 8. Water quality condition rating for State Section 303(d) listed impaired waters (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Rating	Watersheds
Class 1 (good, functioning properly)	274
Class 2 (fair, functioning at risk)	1
Class 3 (poor, functionally impaired)	0

All watersheds within the Chugach National Forest were rated Class 1 (good, functioning properly) for this attribute with one exception: Eyak Lake, which rated as Class 2 (fair, functioning at risk). Eyak Lake was placed on the 303(d) list in 2002-03 for non-attainment of the petroleum hydrocarbons oils and grease standard for petroleum products as a result of above ground storage tank spills. Remedial actions at the Cordova Electric power plant on Eyak Lake have been effective at eliminating sheen on the surface of the lake, which was observed in 2005. Groundwater treatment and monitoring is anticipated to continue at this site. Water quality studies were completed in 2005, 2006, and 2009. ADEC removed Eyak Lake from the Category 5/Section 303(d) list and placed the waterbody in Category 2 in the final 2012 report (ADEC, 2013).

A number of beaches in Prince William Sound were previously Section 303(d) listed in 1990 as a result of the petroleum products remaining from the Exxon Valdez oil spill but have been placed in Category 4b because of restoration efforts specified in the Exxon Valdez Restoration Plan.

A number of watersheds that have water quality issues from impacts, such as mining, hydropower facilities and water impoundments, recreational use, roads, sediment, and industrial uses, are not listed in Category 5/Section 303(d) by the state (see map 3 and tables 9 and 10). These water quality impacts are primarily localized effects. Additional water quality issues occur in and around the communities of Seward, Girdwood, Whittier, Valdez, and Cordova, but the water quality impacts from these communities are primarily outside the Chugach National Forest boundary. The results of the condition rating for water quality in the Watershed Condition Classification Framework for the Chugach National Forest (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011) included the following table for the water quality problems not Section 303(d) listed by the state.

Table 9. Water quality condition rating for impaired waters that are not state 303(d) listed

Rating	Watersheds
Class 1 (good, functioning properly)	257
Class 2 (fair, functioning at risk)	18
Class 3 (poor, functionally impaired)	0

No watersheds within this non-state listed category are known to have extensive water quality problems. A number of waterbodies within or near the Chugach National Forest are classified as ADEC Category 3 for water quality impairment (ADEC, 2010), including Bear Creek near Hope, Cooper Creek, Eyak River, Mills Creek, Quartz Creek, Resurrection Creek, and Two Moon Bay. While specific water quality issues have not necessarily been identified on these streams, they have been identified as being of concern for various reasons, which the State of Alaska and Forest Service have documented. Many of these have also been ranked as Alaska Clean Water Action Priorities (ACWA). All of these watersheds received a Class 2 rating. Some watersheds with major highways immediately adjacent to streams or lakes on National Forest System lands also received a Class 2 rating to account for road-derived pollutants.

Table 10. Watersheds within the Chugach National Forest by geographic area that received Class 2 ratings for state non-listed water quality impairments (ADEC, 2013; MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Geographic Area	HUC	Watershed Name	Rating	Comments
Copper River Delta	190104021701	Katalla River	2	Oil remains from Katalla oil field exploration.
	190201041604	Eyak Lake	2	Eyak Lake was ADEC 303(d) listed for hydrocarbons and industrial pollutants in 2010. It was classified as Category 2 in 2012.
	190201041605	Eyak River-Frontal Gulf of Alaska	2	Eyak River is ADEC Category 3 listed.

Geographic Area	HUC	Watershed Name	Rating	Comments
Kenai Peninsula	190203020304	Portage Creek	2	Portage Creek susceptible to highway and railroad pollutants; bank erosion; gravel extraction activities; sewage lagoon.
	190203020401	Headwaters Canyon Creek	2	Streams and lakes receive pollutants from heavy traffic on the Seward highway because of close proximity. Potential water quality impacts from numerous abandoned hard rock mines.
	190203020402	Mills Creek	2	Sediment from Juneau Creek slide, sediment and hydrocarbons from existing placer mining, ADEC Category 3 listing
	190203020403	Outlet Canyon Creek	2	Sediment from Juneau Creek slide; streams receive pollutants from Seward highway because of heavy traffic, historic placer mining and dam construction.
	190203020406	Granite Creek	2	Streams receive pollutants from heavy traffic on the Seward highway because of close proximity.
	190203020407	East Fork Sixmile Creek	2	Streams receive pollutants from heavy traffic on the Seward highway because of close proximity.
	190203020502	Palmer Creek	2	Heavy metals from Swetman Mine and other hard rock mines.
	190203020504	Lower Resurrection Creek	2	Sediment from bank erosion and settling ponds in large scale placer mines, hydrocarbons from existing large scale mining operations, sediment from bank erosion in recreational mining areas, potential mercury from historic placer mining operations.
	190203020706	Bear Creek-Frontal Turnagain Creek	2	Bear Creek is ADEC Category 3 listed, sediment from mining impacts.
	190203021102	Headwaters Quartz Creek	2	Streams susceptible to pollutants from Seward highway, Quartz Creek is ADEC Category 3 listed.
	190203021104	Outlet Quartz Creek	2	Streams and lakes susceptible to pollutants from Sterling Highway (tanker spills known to have occurred in Daves Creek), Quartz Creek is ADEC Category 3 listed.
	190203021403	Stetson Creek-Cooper Creek	2	Sediment from Cooper Creek slide (initiated by hydraulic mining and road), low temperatures in Cooper Creek from dam and dewatering, ADEC Category 3 listed.
	190203021406	Jean Creek-Kenai River	2	Rivers and streams susceptible to pollutants from Sterling Highway.
Prince William Sound	190202011201	Goose Island-Frontal Prince William Sound	2	Sediment into streams from logging roads and landslides.
	190202012105	Port Wells-Frontal Prince William Sound	2	Heavy metals present from Granite Mine (abandoned hard rock mine) and potentially other abandoned mines.

Studies of groundwater in the Cook Inlet Basin and on the Kenai Peninsula indicate that some domestic and public water supply wells yield water containing concentrations of arsenic that exceed the Alaska standard. These studies and samples occurred outside, but in close proximity to the Chugach National Forest boundary and were not included in the WCC analysis (Glass, 1996). It is possible that these concentrations exist in national forest aquifers. Analyses of streambed substrate samples indicate that concentrations of arsenic in the Cook Inlet Basin appear to be naturally high (Frenzel, 2000). Arsenic in surface water is derived primarily from the natural weathering of soils and rocks and from discharge of groundwater. Despite high concentrations in streambed substrate and groundwater samples, detectable arsenic concentrations were documented to be uncommon in surface waters of Cook Inlet basin streams (Glass, 1996).

Despite the majority of the Chugach National Forest watersheds being rated Class 1, water quality concerns exist in a number of watersheds in limited locations. Most impacts and activities that affect stream banks, wetlands, and riparian areas also have the potential to affect water quality. Many of the known water quality impacts are in heavily visited areas close to roads and developed areas. Several campgrounds, recreational areas, and outhouses are now within riparian management zones since rivers have shifted and eroded banks following floods. Additionally, several outhouses are located in poor proximity to the campground public water systems. Changes in management and restoration of these areas could improve the existing conditions. Mechanisms are in place to mitigate the impact of Forest Service activities, such as best management practices (BMPs), reclamation, and access control. However, increased use and activities within the national forest coupled with climate change may increase the potential for impact to water quality in developed areas.

Overall Current Watershed Condition and Trends

Using all of the core national watershed condition indicators and attributes produces the overall results of the Chugach National Forest watershed condition rating, as displayed in table 11 and map 2 (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011; Potyondy & Geier, 2010).

Table 11. Overall current watershed condition ratings for the Chugach National Forest (adapted from MacFarlane et al. 2011)

Rating	Watersheds
Class 1 (good, functioning properly)	273
Class 2 (fair, functioning at risk)	2
Class 3 (poor, functionally impaired)	0

These watershed condition classifications were based only on watersheds within the Chugach National Forest. In a draft report by MacFarlane et al. (2011), it was noted that 270 watersheds were rated Class 1, and 5 watersheds were rated Class 2. Three of these Class 2 watersheds were not acknowledged as Class 2 in the draft final assessment (Zemke, Develice, and McFarlane, personnel communication, 2013) due to a question of reliable data spanning across lands of other ownership. Management of watersheds entirely or partially outside the Chugach National Forest may have cumulative effects on the condition class rating of these watersheds; however, the reliability of data makes quantifying it at this time difficult. The two Chugach National Forest watersheds that remain rated as Class 2 (fair, functioning at risk) in the draft final are Resurrection Creek near Hope and Cooper Creek near Cooper Landing.

Overall, the majority of Chugach National Forest watersheds are in a good, functioning properly condition (Class 1). Much of this may be attributed to a combination of the glacial coverage and roadless character of the national forest. Minimal human impacts exist on 64 percent of the watersheds with 21 percent of the watersheds containing greater than 50 percent glacier coverage and 43 percent of the watersheds dominantly roadless and/or only accessible by boat and/or floatplane. Variable degrees of human impacts exist in 36 percent of the watersheds with half of these located along road systems (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011).

The major sources of human impacts to watersheds within the Chugach National Forest, particularly to stream channel morphology, include bank degradation from recreational uses, such as fishing the Russian River, OHV trail use on some areas within the Copper River Delta, historic placer mining on Resurrection and Cooper Creeks, existing placer mining operations, gravel extraction (such as in Portage Valley), and roads. In high use areas within the national forest, bank erosion from angler trampling has been a persistent problem and has been difficult to address. The construction of angler trails, boardwalks, and river access stairs on the Russian River in conjunction with bank reconstruction has improved some of these conditions. Rerouting OHV trails and user education have also benefited areas within the Copper River Delta. Other restoration projects, such as Resurrection Creek (Phase I), have successfully dealt with historic mining impacts as will future anticipated projects (Resurrection Creek Phase II and Cooper Creek).

Ecosystem Integrity

Watershed condition reflects a range of variability from natural (functioning properly) to degraded (severely altered state or impaired). Watersheds that are functioning properly have terrestrial, riparian, and aquatic ecosystems that capture, store, and release water, sediment, coarse woody debris, and nutrients within the natural range of variation for these processes. When watersheds are functioning properly, they create and sustain functional terrestrial, riparian, aquatic, and wetland habitats that are capable of supporting diverse populations of native aquatic and riparian dependent species. In general, the greater departure from the natural state, the more impaired the watershed condition is likely to be. Watersheds that are functioning properly are commonly referred to as healthy watersheds. Healthy watersheds provide high water quality, recharge streams and aquifers, and are more capable of moderating climate vulnerability and providing long term soil productivity. These watersheds generally exhibit strong integrity and create and sustain resilient and adaptive terrestrial, riparian, aquatic, and wetland habitats that support diverse populations of plants and animals capable of rapid recovery from natural and human disturbances.

Because 99 percent of Chugach National Forest watersheds are in Class 1 (good, functioning properly), they are considered to have good integrity and are more likely to recover to the desired condition when disturbed by large natural disturbances or land management activities. Despite this, concerns associated with human impacts exist in a number of watersheds in limited locations. A list of anticipated increased impacts to watershed condition that could affect integrity if not addressed through management follows:

- Erosion, sedimentation, and wetland damage from user trails (foot and OHV), particularly on the Copper River Delta
- Stress on streambanks along the Russian River, despite management efforts to restore and protect banks
- Stress on streambanks associated with increased back country trail use or use by pack animals (consider rerouting trails where they are close to streams/riparian areas)
- Continued risks of introduced species through waders, intentional pet release, off-site bait use, and organisms that attach to boats, fishing gear, or floatplanes
- Sedimentation and pollutants associated with backcountry motor vehicle use
- Fecal coliform pollution from recreation related human waste
- Loss of stream channel, stream bank and riparian vegetation integrity, and sedimentation from mining activities, including recreational dredging
- Acid drainage from hard rock mines
- Release of mercury during stream restoration activities and placer mining from historical placer mined areas

A number of watershed restoration projects have occurred within the national forest within the last decade. These improvements have included large scale stream and riparian restoration projects (i.e., Resurrection and Daves creeks), small scale stream bank restoration projects (i.e., Kenai and Russian rivers), trail improvements, and abandoned mine cleanup efforts. The Forest Service has also been implementing watershed restoration work and monitoring on lands affected by the Exxon Valdez oil spill, including acquired lands on Knowles Head. All of these projects have improved the functions of streams and riparian areas and water quality associated with impacts from past or historic land management and current activities. Continuing to restore these watersheds will maintain and improve watershed integrity.

Information Needs

Currently the Chugach National Forest has limited baseline data for assessing climate change, particularly in regards to water quality and water quantity. Since 2007, the number of USGS stream gage network sites funded and supported by the Forest Service has declined from three to one. Sixmile Creek on the Kenai Peninsula is the sole funded gage. There is limited stream temperature, dissolved oxygen, hydrocarbons, and turbidity data, and there are very few stream gages or ground water wells in the national forest. Partners, such as the Kenai River Watershed Forum, USGS, and the Pacific Northwest Research Station, have collected valuable data in limited locations. Strengthening and continuing these partnerships into the future will aid in achieving agency goals. The Arctic, North Pacific, Northwest Boreal, and Western Alaska Landscape Conservation Cooperative (LCCs) along with the Alaska Climate Science Center (ACSC), the Alaska Climate Change Executive Roundtable (ACCER), many state and Federal agencies, and others have all identified the need to better understand the changes in hydrology due to climate change as a high priority for Alaska. Water temperature monitoring and forecasting were identified as a high priority information need. Data on national forest water quantity and water quality will be necessary to project future ecosystem trends from the aforementioned stressors and make meaningful recommendations for future resource management. Heavily used winter snowmachine areas may be contributing elevated levels of hydrocarbons in key locations, such as Granite Creek, Placer Valley, and the Lost Lake area. It may be valuable to acquire baseline data for these systems for comparison to data in the future.

There is limited data on the quantity, quality, timing, and distribution of groundwater resources and groundwater-dependent ecosystems within the national forest. Information on national forest groundwater resources will likely be valuable if there is more demand for surface water or consumptive groundwater use associated with increased water use or development. It will also be valuable for understanding the contributions to the aquatic ecosystems and their role in acting as refugia for buffering climate change impacts.

Adequate data on aquatic invasive species that may be transported to Chugach National Forest waterways, lakes, and rivers via floatplane and boat use is essential to prevent the spread and degradation of watershed health.

Aquatic Ecosystems—Fish

The section describes the integrity of aquatic ecosystems associated with the Chugach National Forest. The perspective is fish and the aquatic habitats they depend upon for production and survival. The metrics devised to examine aquatic ecosystem integrity are intended to estimate the trend, range of variation, function, and relative importance of key aquatic ecosystem characteristics. The approach was shaped by the reality that some of the existing data relevant to the aquatic ecosystems of the Chugach National Forest are limited across the assessment area.

Relevant information is presented in a topical order that includes: a description of the aquatic ecosystems being evaluated, a discussion of key aquatic ecosystem characteristics, an estimate of aquatic ecosystem condition, an assessment of aquatic ecosystem integrity, and a documentation of important information needs.

Relevant Information

- The Chugach National Forest is a patchwork of five different kinds of aquatic ecosystems distributed across 607 stream systems. The pink/chum salmon aquatic ecosystem is most common, with 254 systems assigned to this classification. With only 24 stream systems identified, the Chinook salmon aquatic ecosystem is least common.
- The sockeye/coho salmon aquatic ecosystem is the most common in the Copper River Delta geographic area representing 43 percent of the stream systems. Prince William Sound is dominated by the pink/chum aquatic ecosystem with 51 percent of the stream systems. The Chinook salmon and Dolly Varden char aquatic ecosystems are the most common for the Kenai Peninsula geographic area, together representing 64 percent of the stream systems.
- The presence of salmon is one of the defining features of ecosystems within the Chugach National Forest. Decaying salmon carcasses infuse critically important marine derived nutrients into aquatic, riparian, and terrestrial ecosystems.
- Beginning about 100 years ago, up to 60 percent of each year's salmon return has been caught in commercial fisheries. As a result, fewer salmon are reaching spawning grounds than in historical times, which means that the source of marine derived nutrients into these ecosystems has been reduced.
- Of the five salmon species examined, the Chinook salmon aquatic ecosystem had the lowest index for ecosystem integrity, while the coho salmon aquatic ecosystem had the highest index. The uncertainty associated with these scores was much greater than the differences between any two aquatic ecosystems.
- Based on modeling results, the salmon habitat and species distributions will be vulnerable to climate change. During the next 50 years, as the warm water and cold water boundaries change along the Alaska coastline, the specific habitat suitability for salmon species may dramatically affect the distributions that are currently observed (Abdul-Aziz, Mantua, & Myers, 2011).

Aquatic Ecosystems—Fish Evaluated

Within each of the three geographic areas of the national forest there is considerable variation in both stream system character and the species that are present. The occurrences of key and ecologically distinct fish species were used as the means to identify five different aquatic ecosystems. These are distributed across the Chugach National Forest landscape in a fine-scaled patchwork of stream systems.

This evaluation is based on using fish as an indicator of aquatic ecosystem character and function. The underlying assumption is that the condition of primary fish species can be informative of the overall condition of the aquatic ecosystem where they occur (Irvine & Riddell, 2007). The primary advantage of using this approach is that data of sufficient detail and scope were readily available making it possible to make these classifications with some confidence for most of the Chugach National Forest. There are other means to classify aquatic habitats, such as using channel types (see Aquatic Ecosystems—Watersheds); however, they require some additional understanding of the functional relationship between stream habitat character and how this influences species distribution and relative productivity. Such information is currently limited for stream systems within the Chugach National Forest.

Salmon or other members of the salmon family (e.g., char and trout) were used as a means to identify aquatic ecosystems because they are the most dominant species in the aquatic ecosystems of the Chugach National Forest. Five salmon species are present in varying amounts and distribution: Chinook, coho, sockeye, chum, and pink salmon. Salmon have several unique features. First, they are anadromous, meaning their life history includes a freshwater phase dedicated to reproduction and early life and a marine phase where they take advantage of the rich ocean environment for rapid growth and transition to adulthood. For Chinook and coho salmon, the freshwater phase is longer; however, all species depend on the freshwater environment to complete their life cycle. While access to freshwater is an absolute requirement of these species, the necessity of the marine environment is not as fixed. For example, kokanee, the resident form of sockeye, naturally occur in many land-locked lake systems. When introduced into novel freshwater environments, such as the Great Lakes, all five species have completed their life cycle without a migration to the marine environment. Therefore, it appears that while salmon can adapt to the loss of the marine environment, they cannot survive if they are deprived of the freshwater environment. In southcentral Alaska, much of this freshwater environment is represented by watersheds that occur within the Chugach National Forest. Nearly all salmon populations in this area make extensive migrations into the North Pacific Ocean, often thousands of miles from their place of birth. However, once these fish have achieved sufficient growth to mature, they navigate their way back to their natal stream where they spawn and shortly thereafter die.

The fidelity of salmon to their home stream has important biological implications. Among these is that salmon tend to form independent populations that typically exist at a relatively fine geographic level of detail. Because of their relative isolation, each population tends to follow its own path to maximize genetic adaptation to the local conditions of the home stream and associated migration pathways. The end result is that, during a sufficient amount of time, a considerable amount of geographically fine-scaled population diversity can evolve across the salmon landscape. Not only does this diversity benefit the viability of individual populations, it also provides a raw source of genetic variation that helps the species as a whole adapt when large scale conditions change, such as during periods of glacial retreat or advance.

Fidelity of salmon to their home stream varies and is not 100 percent. A portion of each year's return stray to other stream locations. Under natural conditions, it is thought that stray fish from other populations generally comprise 10 percent or less of the spawning population (Quinn, 1997). Because genetic differences are often found between adjacent salmon populations, the genetic impact of this background straying rate does not appear to prevent the divergence and adaption of most local populations. This straying behavior is also ecologically advantageous as a means for salmon and related species to colonize newly accessible habitats (Griswold, 2002).

Perhaps the most significant feature of the salmon life history is that after spawning in their home stream, they die and their carcasses decompose to provide a substantial, annual source of marine derived nutrients to the aquatic ecosystem. The importance of this enrichment to the aquatic ecosystem has been demonstrated in a number of studies (Cederholm, Kunze, Murota, & Sibatani, 1999; Helfield & Naiman, 2001; Rinella, Wipfli, Stricker, Heintz, & Rinella, 2012; Holtgrieve & Schindler, 2011). The contribution of salmon does not stop at the water's edge. Not only are salmon a primary food source for top terrestrial predators, such as bears, eagles, and mink; the marine nutrients find their way into the terrestrial ecosystem, including lichens, trees, and other riparian vegetation. Coastal brown bear, the world's largest land-based predator occurs in Alaska because of salmon. Wilson and Halupka (1995) use salmon in their role as contributors to a broad scale ecological impact to define what they refer to as a keystone species.

Aquatic ecosystem descriptions

Chinook salmon aquatic ecosystem

Chinook salmon (*Oncorhynchus tshawytscha)* aquatic ecosystems occur in moderate to large stream systems that have a diversity of rearing habitats for juveniles. The habitat requirements are somewhat similar to that of the coho salmon. For every location within the Chugach National Forest where Chinook salmon are known to exist, coho salmon are also present. However, there are many more locations within the Chugach National Forest where coho salmon occur and Chinook salmon are absent. The patchy occurrence of Chinook salmon among the many streams occupied by coho salmon is evidence that there are habitat differences that have thus far not been clearly identified.

Coho salmon aquatic ecosystem

These aquatic ecosystems are generally associated with watersheds that have no lakes yet contain coho salmon (*Oncorhynchus kisutch*). Sockeye salmon are usually missing from these systems because there is no lake habitat for sockeye juveniles. However, these systems do contain freshwater habitat for older, one- to three-year-old juvenile coho salmon. Such stream habitat is essential to the life cycle of this species. These habitat characteristics are often associated with larger streams having a steeper gradient than those used by pink and chum salmon. The density of spawners in such watersheds is low, because the population is naturally limited by the amount of juvenile rearing habitat.

Sockeye/coho salmon aquatic ecosystem

These aquatic ecosystems are represented by watersheds that contain lakes or lake-like habitat, which is generally a requirement for sockeye salmon (*Oncorhynchus nerka*) for spawning and juvenile rearing. Coho salmon are also typically found in these systems, often in large numbers, utilizing the lake habitat for juvenile rearing and overwintering. Pink and chum salmon are less common and frequently absent, especially in these aquatic ecosystems in the Copper River Delta. It is likely there are cryptic, yet to be discovered characteristics of these habitats that make them less favorable to pink and chum salmon.

Pink/chum salmon aquatic ecosystem

This aquatic ecosystem is dominated by pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*). The streams that characterize this aquatic ecosystem are usually small, with a short spawning reach that often includes a sizable portion within the intertidal zone. These streams typically contain adequate spawning gravel and a sufficient water supply to facilitate the incubation of eggs during the winter months. Another characteristic feature of this aquatic ecosystem is that the streams have very little habitat for older-aged juvenile salmon. Consequently, coho and Chinook salmon, which need this type of juvenile habitat, are uncommon in these streams. The density of adult pink and chum salmon during the spawning season is typically very high. The pink/chum salmon aquatic ecosystem is prevalent across much of Prince William Sound.

Resident Dolly Varden char aquatic ecosystem

The primary feature of this type of aquatic ecosystem is that it cannot be reached by anadromous fish because of naturally occurring barriers to upstream migration; usually in the form of waterfalls. The dominant species in such non-anadromous areas is Dolly Varden char (*Salvelinus malma*). Although in some locations cutthroat trout (*Oncorhynchus clarki*) or rainbow trout (*Oncorhynchus mykiss*) fulfill this role. Fish that exist in this aquatic ecosystem must complete their entire lifecycle in freshwater. Any members that emigrate to the sea as juveniles are not able to return to their natal home as adults because of isolating migration barriers. These systems do not have a regular infusion of marine derived nutrients as do the other four aquatic ecosystems where anadromous fish dominate. The density and biomass of fish is also much lower. Streams tend to be smaller and higher gradient than those in the other aquatic ecosystems.

Aquatic ecosystem classifications

The Anadromous Waters catalog maintained by ADF&G is the source of information used to identify those stream systems within the Chugach National Forest that contain anadromous fish (Johnson & Blanche, 2012). This catalog also provides the location of fish species. Not every watershed listed in the catalog was used in this evaluation. Using the interactive online mapping feature provided by ADF&G, stream systems that were very small were excluded from this analysis. Using this selection process, 405 salmon stream systems were considered. Of this total, the 330 are in Prince William Sound (see table 12). For the Kenai Peninsula and Copper River Delta, 41 and 34 stream systems were identified, respectively.

No information is readily available to determine how many streams should be classified as belonging to the Dolly Varden char aquatic ecosystem. The number of stream systems reported here for the Dolly Varden char aquatic ecosystem are very rough estimates with values set to equal half the total count of anadromous stream systems. The genesis of this *ad hoc* approximation is the informal yet frequent observations by Forest Service biologists of Dolly Varden in stream sections upstream of natural salmon barriers, such as waterfalls. These non-anadromous zones were treated as a separate stream system for the purposes of this assessment. Conceptually, the salmon migration barrier was used to split a stream system into two ecosystem types. For example, the anadromous zone downstream of a barrier waterfalls might be classified as belonging to the coho salmon ecosystem based on the presence of that species with the portion upstream classified as belonging to the Dolly Varden ecosystem. It is likely that if a comprehensive inventory of non-anadromous waters was actually conducted the number of stream systems classified into the Dolly Varden char aquatic ecosystem would be greater than the estimate (202 stream systems).

Under this classification approach, any of the five aquatic ecosystems may contain other fish species in addition to those that define it. For example, a sockeye/coho salmon aquatic ecosystem may frequently contain pink and chum salmon. However, the presence of sockeye salmon generally means that fish have access to a lake or lake-like habitat, including sloughs and oxbow ponds. Stream systems with lakes function differently ecologically and have different physical attributes than those without lakes. Therefore, even though pink and chum salmon may be present, the defining feature is the presence of sockeye salmon.

Across the Chugach National Forest, 42 percent of the stream systems were assigned to the pink/chum salmon aquatic ecosystem (see table 13). Least common were stream systems classified as belonging to the Chinook aquatic ecosystem (4 percent). These aquatic ecosystems were not evenly distributed across the three geographic areas. Within the Copper River Delta, the dominant aquatic ecosystem was sockeye/coho, accounting for 43 percent of the stream systems. For Prince William Sound, the pink/chum salmon aquatic ecosystem was the most common, with 51 percent of the stream systems in this category. In the Kenai Peninsula, the Dolly Varden char aquatic ecosystem (33 percent) and the Chinook salmon aquatic ecosystem (31 percent) were the primary aquatic ecosystems. In summary, each of the three geographic areas was dominated by a different aquatic ecosystem.

Table 12. Number of Chugach National Forest watersheds in each of the five aquatic ecosystems identified in this assessment by geographic area

Geographic Area	Aquatic Ecosystem					Totals
	Chinook salmon	Coho salmon	Sockeye/coho salmon	Pink/chum salmon	Dolly Varden char*	
Copper River Delta	4	8	26	3	20	**61**
Kenai Peninsula	16	4	13	1	17	**51**
Prince William Sound	4	45	31	250	165	**495**
Totals	**24**	**57**	**70**	**254**	**202**	**607**

*The number of stream systems that should be classified as the Dolly Varden char type aquatic ecosystems is not known, the numbers provided here are a rough approximation based on the 50 percent of the total number of salmon stream systems (see text).

Table 13. The proportion of fish bearing stream systems in the geographic areas assigned to Chinook, coho, sockeye/coho, and pink/chum salmon and Dolly Varden char aquatic ecosystems

Geographic Area	Aquatic Ecosystem				
	Chinook salmon	Coho salmon	Sockeye/coho salmon	Pink/chum salmon	Dolly Varden char*
Copper River Delta	0.07	0.13	0.43	0.05	0.33
Kenai Peninsula	0.31	0.08	0.25	0.02	0.33
Prince William Sound	0.01	0.09	0.06	0.51	0.33
Totals	**0.04**	**0.09**	**0.12**	**0.42**	**0.33**

*The percentage of stream systems that should be classified as the Dolly Varden char type aquatic ecosystems is not known, the numbers provided here are a rough approximation based on the 50 percent of the total number of salmon stream systems (see text).

Key Ecosystem Characteristics

The five aquatic ecosystems identified here have a diversity of physical, biological, and anthropomorphic attributes. Some of these are relatively fixed, such as the location of barriers to upstream salmon migration or stream gradient. Others, like marine survival, are more cyclical and change over longer periods of time. Some, such as precipitation, vary annually. All contribute to the character and dynamic function of these aquatic ecosystems.

Physical attributes

Stream length

The amount of salmon-producing habitat for a given stream is directly related to the stream's length. Streams with many miles of habitat accessible to salmon, in general, produce more fish than short streams. Most streams within the Chugach National Forest are relatively short because of the steep mountain topography and the close proximity to the ocean (less than 10 miles long). In Prince William Sound, it is common for salmon to have access only to the intertidal portion of the stream. However, even with these limitations, the production of salmon in this region is substantial. Conversely, the Copper and Kenai rivers are large systems with many miles of salmon-bearing waters, a portion of which is outside of the Chugach National Forest boundary.

Stream gradient

Stream gradient, while relatively fixed, has a strong influence on fish production potential and species distribution. Very steep gradient streams constrain fish passage and do not contain the pools necessary for juvenile rearing of salmon. Dolly Varden char, cutthroat trout, and rainbow trout can be found in quite steep and small streams. Streams that are moderate in gradient (2 to 4 percent) are generally not good habitat for chum and pink salmon and are more often preferred by Chinook and coho salmon. All species can be found in lower gradient stream sections; however, pink and chum salmon tend to utilize these areas most.

Migration barriers

Barriers to upstream migration of salmon, usually waterfalls, impact the distribution of aquatic species. The height of the falls and the timing of run with regard to flow conditions can have an impact on the ability of anadromous species to use the area above moderate sized barriers. For example, coho and Chinook can negotiate falls in the range of 8 to 10 feet high, while pink and chum salmon are likely blocked by any falls greater than 4 feet. Waterfalls that are barriers to all anadromous fish provide the isolation mechanism that is needed for the Dolly Varden char aquatic ecosystem to flourish, as this aquatic ecosystem exists only where it is isolated from anadromous fish.

Precipitation and stream flow

The amount of precipitation, when it falls and whether or not it is mostly in the form of snow or rain, has a strong influence on stream flow characteristics and stream temperature. Variations in precipitation and temperature are substantial across the Chugach National Forest as noted in climate change portion of the assessment, and this has a bearing on the type of stream. Chugach National Forest stream types may include glacier driven, snow driven, rain driven, and groundwater driven. Variations in precipitation have the greatest potential to impact streams that are either snow or rain driven. Highest flows for snow driven streams occur during the period of spring snowmelt. Highest flows for rain dominated streams occur during the late summer months when rainfall amounts are typically greatest. These differences, along with a corresponding water temperature signature, have a major impact on which timing window is best for spawning, incubation, and post-emergence survival of newly hatched juvenile salmon (fry). These hydrologic characteristics may also play a role in the suitability of a watershed for one species over another.

Water turbidity

Streams with high turbidity generally represent suboptimal conditions for spawning and rearing conditions for salmon, char, and trout, although there may be some advantage of turbid waters in terms of reducing the vulnerability of juvenile salmon to predation. Many streams within the Chugach National Forest carry a heavy sediment load from glaciers melting during the warmer portion of the year. This greatly reduces light penetration into the water column and retards phytoplankton growth. This impact is transferred up the food chain and ultimately means juvenile fish have less to eat during the primary growing season. As a result, waters carrying a heavy glacial sediment load are less productive. Water turbidity from glaciers also affects the lakes that juvenile sockeye rear in. Annual variations in the rate of glacial melt and associated lake turbidity can have dramatic year to year impacts on sockeye salmon production.

Spawning gravel quality

Heavily compacted or sediment laden gravel is unfavorable for the incubation of salmon eggs. Freshly spawned eggs must survive for six to nine months in the same location before the young hatch and emerge in the spring. This is a critical stage in the life history, as the survival rate during this period is typically in the range of 10 percent (Bradford, 1994). Lower survival rates are associated with streams having heavy silt loads, flooding, winter dewatering, and ice scouring. Heavy silt, whether from human-caused sources, such as road building, or natural ones, such as glaciers, reduces inter-gravel water circulation and oxygen supply to the incubating eggs causing them to suffocate. This will lower a population's overall egg to fry survival rate and result in fewer salmon in the next generation.

Juvenile rearing habitat

Juvenile coho and Chinook salmon as well as all char and trout need stream habitats that will sustain them for at least 1 to 4 years. Streams with the largest portion of this required habitat will produce more fish than those streams that are mostly lacking such habitat. This specialized habitat is usually associated with pools and some type of structure or hiding cover, usually in the form of woody debris.

Biological attributes

Marine survival cycles

Marine survival of juvenile salmon fluctuates widely. Perhaps more than any other factor, it is the survival rate during the marine phase of a salmon's life history that best predicts the subsequent run-size, catch, and level of marine derived nutrients that are infused back into the freshwater aquatic ecosystem. Survival rates, usually expressed as juvenile to returning adult survival, are difficult to obtain for wild populations. However, where such data exist, they have been found to correlate well with cyclic patterns of salmon abundance. In other words, periods of high marine survival result in large salmon returns, periods of low marine survival result in fewer numbers of returning salmon.

Marine-derived nutrients

Salmon have a major influence on the productivity and function of aquatic ecosystems in Alaska as well as terrestrial ecosystems. Their presence provides a nutrient subsidy that is critical to maintain the productivity of the aquatic ecosystem (Hicks, Wipfli, Lang, & Lang, 2005). This influence comes from a boost of nutrients from decomposing salmon carcasses in fresh water systems. The carcasses are supplied each year after the spawning season is over as the salmon die and decompose. This seasonal boost of nutrients increases stream productivity significantly and benefits the capacity of the system to produce all forms of aquatic life, including fish. Without this annual nutrient supply, the productivity of these systems would be much reduced, a factor of high significance especially for Chinook, coho, and sockeye salmon as a substantial part of their life history occurs in freshwater. Salmon are also important to the terrestrial ecosystem, benefitting both wildlife and riparian vegetation.

Species diversity

Interactions among different naturally occurring species have an influence on the function of aquatic ecosystems and the productivity of individual species. Although at this time these interactions are poorly understood, changes in the relative number and distribution of these species provides an important indicator of aquatic ecosystem disturbance.

There are at least 19 fish species that occupy the Chugach National Forest (see table 14). In terms of abundance, economic value, cultural significance, and ecological importance, the five species of Pacific salmon play the primary role. In addition, there are six additional anadromous species that occupy national forest waters and are also part of the indigenous aquatic ecosystem, including steelhead trout, sea-run cutthroat trout, sea-run Dolly Varden char, eulachon, Pacific lamprey, and threespine stickleback. As displayed in table 14, some of these species are widespread and others have a very limited distribution. For example, eulachon return in large numbers annually to specific basins (e.g., Twentymile and Copper rivers).

The Chugach National Forest also contains a number of fish species that spend their entire life in freshwater (see table 14). Included are: Dolly Varden char (resident form), rainbow trout (resident form), cutthroat trout (resident form), arctic char, two species of whitefish, ninespine stickleback, and three sculpin species.

Table 14. Common name, scientific name, and general distribution of fish produced in the Chugach National Forest

Common Name	Scientific Name	Distribution
Chinook salmon	*Oncorhynchus tshawytscha*	Across the national forest
Coho salmon	*Oncorhynchus kisutch*	Across the national forest
Sockeye salmon	*Oncorhynchus nerka*	Across the national forest
Chum salmon	*Oncorhynchus keta*	Across the national forest
Pink salmon	*Oncorhynchus gorbuscha*	Across the national forest
Steelhead trout	*Oncorhynchus mykiss (anadromous form)*	Eastern national forest (Copper and Martin rivers) and Turnagain Arm tributaries
Cutthroat trout	*Oncorhynchus clarki*	Scattered across Prince William Sound and the Copper River Delta
Rainbow trout	*Oncorhynchus mykiss*	Kenai Peninsula, Copper and Martin rivers
Dolly Varden char	*Salvelinus malma*	Across the national forest
Arctic char	*Salvelinus alpinus*	Cooper Lake (single location)
Lake trout	*Salvelinus namaycush*	Kenai Lake
Arctic grayling	*Thymallus arcticus*	Crescent and Grayling Lakes (introduced species)
Round whitefish	*Prosopium cylindraceum*	Kenai Peninsula, Copper River
Humpback whitefish	*Coregonus oidschian*	Copper River
Eulachon	*Thaleichthys pacificus*	Turnagain Arm, Copper River Delta
Burbot	*Lota lota*	Juneau Lake (single location)
Coast Range sculpin	*Cottus aleuticus*	Likely across the national forest
Prickly sculpin	*Cottus asper*	Likely across the national forest
Slimy sculpin	*Cottus cognatus*	Likely across the national forest
Threespine stickleback	*Gasterosteus aculeatus*	Across the national forest, often anadromous
Ninespine stickleback	*Pungitius pungitius*	Kenai Peninsula, infrequent
Pacific lamprey	*Entosphenus tridentata*	Copper and Kenai rivers

Anthropogenic attributes

Fishery impacts

Salmon, char, and trout are all caught in fisheries. As a result, a portion of each year's production is removed from the population prior to spawning. Although Chugach National Forest salmon populations have sustained this often significant annual source of mortality for many years, it is not clear what the long term ecological effect may be of fewer salmon carcasses on the spawning grounds as a result of these fisheries.

The ecological character of most anadromous streams is likely different today than in historical times before the start of large-scale salmon fisheries. Evidence for this change is provided by Rodgers et al. (2012) in the reconstruction of salmon population numbers for the past 500 years based on the evaluation of stable nitrogen isotopes in sediments from 20 lakes in western Alaska. In the 400 years before 1900, salmon populations fluctuated independently from each other in a non-synchronous pattern. However, virtually all spawning populations declined after 1900, which coincides with the start of large-scale fisheries. The authors infer that these fisheries have reduced the infusion of salmon derived nutrients into the freshwater aquatic ecosystem by 60 percent relative to the historical baseline from 1500 to 1900.

Hatchery influence on wild salmon

Hatchery fish are common in Prince William Sound and in the lower Kenai Peninsula. A number of studies on coho, Chinook, and steelhead have demonstrated that hatchery and wild fish spawning under natural conditions differ considerably in their relative ability to produce surviving offspring (Araki, Berejikian, Ford, & Blouin, 2008; Buhle, Holsman, Scheuerell, & Albaugh, 2009; Chilcote, 2003; Leider, Hulett, Loch, & Chilcote, 1990). The magnitude of the difference is large. Chilcote et al. (2011) estimated that a naturally spawning population composed entirely of hatchery fish would have approximately one-tenth the reproduction rate as a population composed entirely of wild fish. Such differences between hatchery and wild fish have not been demonstrated for salmon populations that occur within the Chugach National Forest, although Hilborn and Eggers (2000) concluded that hatchery pink salmon have replaced rather than reproductively supported wild pink salmon populations in Prince William Sound.

Invasive species

Invasive species via predation and competition for food and space can disrupt the functional stability aquatic ecosystems. In terms of fish, the primary threats to southcentral Alaska are northern pike (*Esox lucius*) and Atlantic salmon (*Salmo salar*). Northern pike are not native to the Chugach National Forest, but indigenous populations do exist in Alaska. This species has been found in lakes on the western portion of the Kenai Peninsula (likely due to unauthorized introductions), but none have yet been reported within the national forest. Atlantic salmon, likely escapees from commercial pen-rearing hatchery operations in British Columbia, have been recovered in the marine environment near Cordova. In general, Atlantic salmon do not seem to be able to establish self-sustaining natural populations in the streams draining into the Pacific Ocean. The exception is several streams on the east coast of Vancouver Island in British Columbia where natural populations of this species have become established. Invasive invertebrates and fish pathogens also pose a threat to Chugach National Forest aquatic ecosystems, although at this time there is no evidence that any contact has occurred.

Climate change

Salmon and their associated ecosystems are sensitive to climatic variations and the possible effects are many and complex (Bryant, 2009). Anticipated changes in stream hydrologic condition due to climate change will have varying effects on salmon life history. For example, it is expected that warming water temperatures will accelerate the rate at which salmon eggs develop in gravel and this will result in a timing change for hatching and emergence of young salmon that may be too early relative to the optimum ecological window for survival and growth. It is also expected that, up to a certain point, warmer ocean temperatures may improve the growth and survival of salmon in this region. In the recent past, periods of colder ocean temperature have been less favorable to survival of Alaska salmon than when ocean temperatures were warmer (Mantua, 2009).

Oil spills

In 1989, the T/V Exxon Valdez ran aground and 11 million gallons of crude oil were spilled into Prince William Sound. This had an adverse impact on the marine ecology and food webs that salmon depend on. It also impacted the intertidal zone of many streams in Prince William Sound where a large portion of the pink and chum salmon spawn. Most salmon populations are thought to have recovered from this event, although residue from the oil spill is still detectable in the environment.

Since 1989, shipping procedures and oil spill response measures have been implemented to reduce the likelihood of a spill and in the event of another spill help contain the scale of impact. However, oil tankers continue to travel Prince William Sound and the chance of another oil spill has not been eliminated.

Condition and trends

As a means to evaluate the current condition of the aquatic ecosystems, three indicators or elements were selected, including trends in fish abundance, hatchery impact on natural production, and climate change. The primary criteria for selection of these indicators are that they are known to be related to the sustainability of fish populations and their associated ecosystems.

Trends in fish abundance: Chinook salmon aquatic ecosystems

The Chinook aquatic ecosystem in the Kenai Peninsula is represented by the early and late runs of Chinook salmon returning to the Kenai River. Annual numbers of Chinook for both of these runs are based on estimates presented by Begich and Pawluk (2011) and ADF&G (ADF&G, 2014c). Since 1986, there has been a downward trend in both groups of fish, especially in the last 10 years (see figure 3). In addition, the run sizes in 2012 and 2013 were the lowest on record and appear to be outside of the natural range of variation for these two populations. Although the reason for this decline is unknown, it is plausible that the primary factor involved occurs during the ocean phase of the life cycle as Chinook salmon populations from other western portions of Alaska are also in low abundance. The shared ocean environment of these and the Kenai population is the common denominator for all of these Chinook salmon.

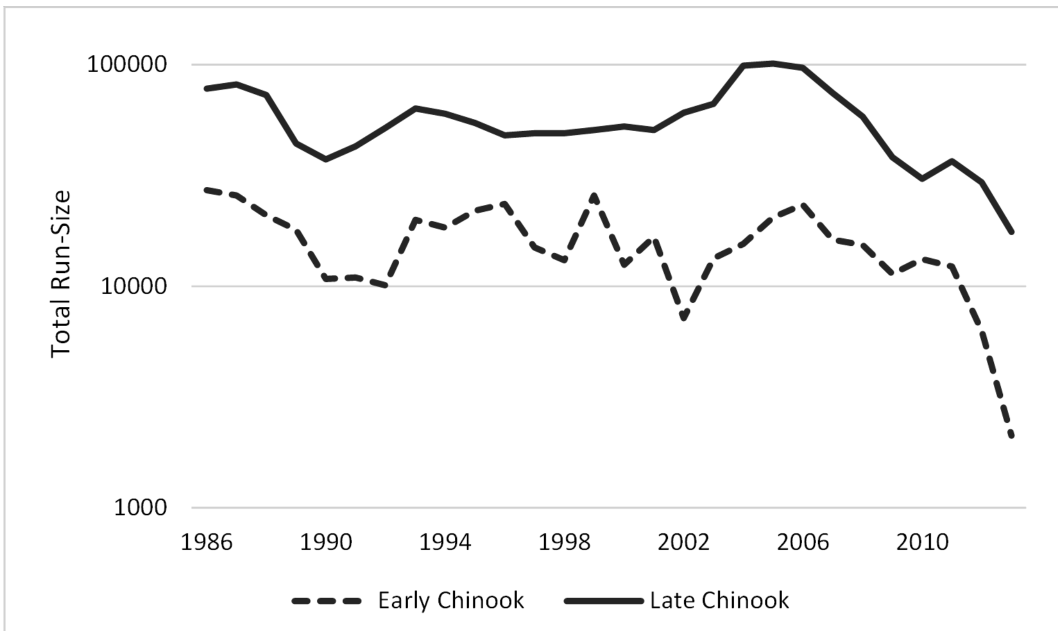


Figure 3. Run sizes for early-run and late-run Chinook salmon returning to the Kenai River from 1986 to 2013 (ADF&G, 2013a; ADF&G, 2014c; Begich & Pawluk, 2011).

Comparable information is not available for Prince William Sound or the Copper River Delta. However, as an index of run size, recreational fishery catch data as reported by Hochhalter et al. (2011) was examined for trends for the Prince William Sound and Kenai Peninsula and compared to recreational fishery data for the Kenai River (see figure 4). The catch for Kenai Peninsula Chinook salmon has declined, most noticeably since 2010. Copper River Delta catch numbers have also declined while the Prince William Sound catch has increased during the same period. The trends for Prince William Sound and the Copper River Delta are further complicated because after the early 2000s, the catch may include an unknown number of hatchery origin Chinook salmon.

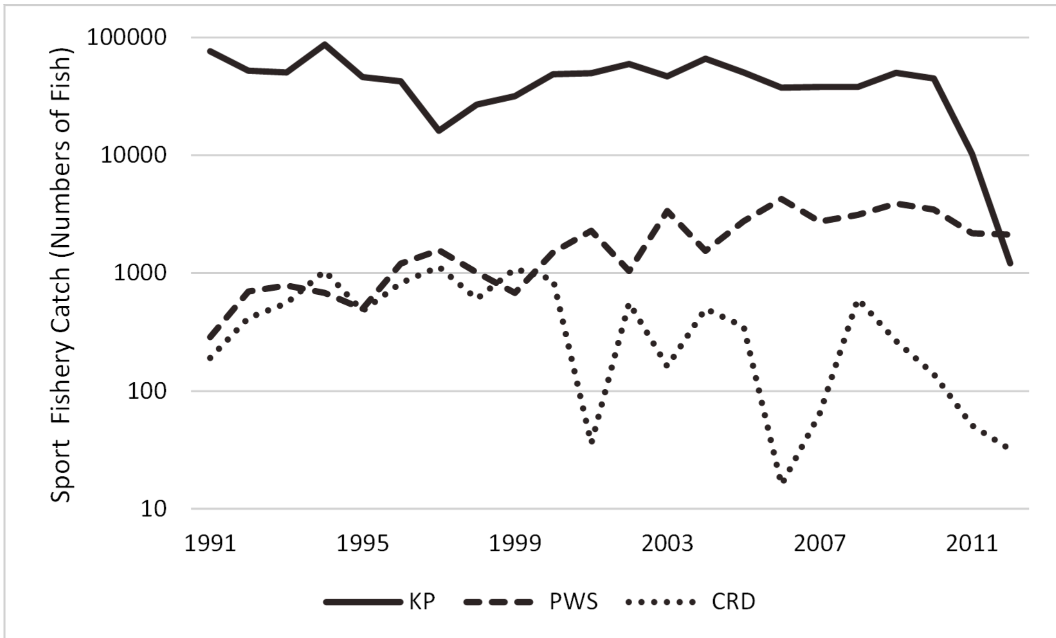


Figure 4. Estimated numbers of Chinook salmon caught in recreational fisheries for the geographic areas from 1991 to 2012 (Begich & Pawluk, 2011; Hochhalter, Blain, & Failor, 2011; ADF&G, 2014c).

Trends in fish abundance: coho salmon aquatic ecosystems

ADF&G's estimates of coho salmon harvested from 1996 to 2012 (caught and kept) for the Copper River Delta, Kenai Peninsula, and Prince William Sound were used to examine trends for those stream systems classified as belonging to the coho salmon aquatic ecosystem (Begich & Pawluk, 2011; Hochhalter, Blain, & Failor, 2011). These data show that there was an upward trend in the harvest of Copper River Delta coho salmon, while for both Kenai Peninsula and Prince William Sound coho salmon, no trends were apparent (see figure 5). This provides only a rough representation of the coho salmon aquatic ecosystem since these harvest estimates include an undetermined number of coho salmon produced from the Chinook salmon and sockeye/coho salmon aquatic ecosystems as well.

While spawner escapement data that is watershed specific would provide much better means to assess trends for coho salmon, such information is nearly unavailable. The problem is that salmon spawning surveys are rarely done from mid-September through mid-November when many coho spawn. There are two reasons for this, the weather conditions at this time of year are not conducive for conducting stream surveys and the fishery management need for coho salmon escapement numbers is less than for other, more intensively managed species, such as pink salmon.

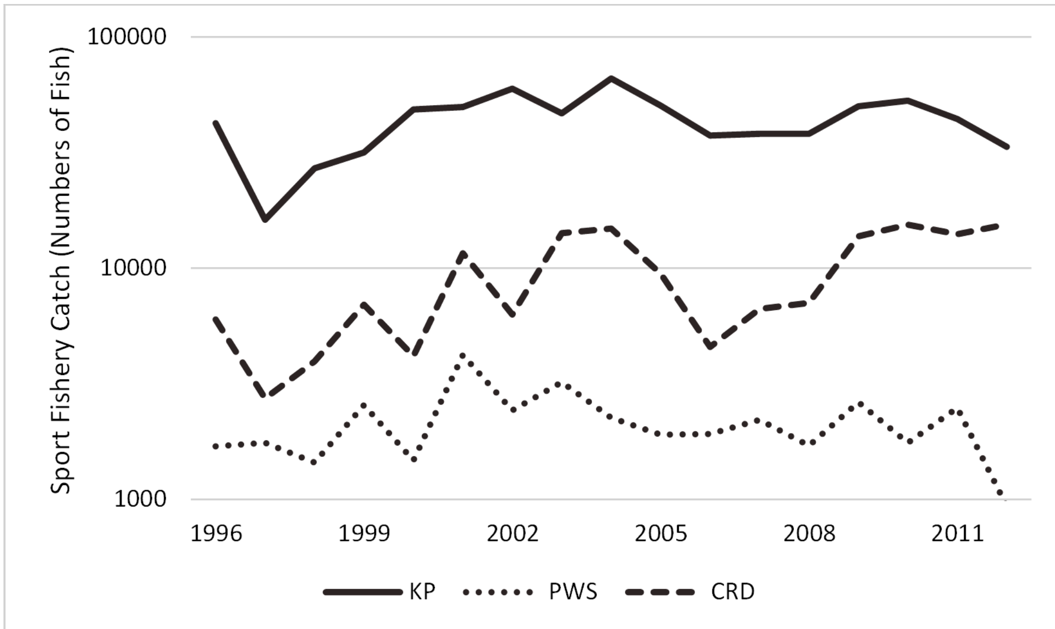


Figure 5. Estimated numbers of coho salmon caught in sport fisheries as reported by ADF&G for the geographic areas from 1996 to 2012 (Begich & Pawluk, 2011; Hochhalter, Blain, & Failor, 2011).

Trends in fish abundance; Sockeye/coho salmon aquatic ecosystems

Information available for trends in the number of coho salmon for each area has been reported previously (see figure 5). For sockeye salmon, the data used here were estimates of the number of sockeye salmon spawning each year in several key producing stream systems in each geographic area of the Chugach National Forest (Botz, Sheridan, Weise, Scannell, Brenner, & Moffitt, 2013; Shields & Dupuis, 2012). Based on these data, there is an upward trend in the number of sockeye salmon for the Kenai Peninsula (in this case represented by the Kenai River). In contrast, the trend in number of sockeye spawners for the Prince William Sound index stream systems (Coghill and Eshamy stream systems) decreased (see figure 6). The trend for Copper River Delta streams also appears to be decreasing, although the dataset does not start until 2001 and this is probably too short of an interval to establish long term patterns.

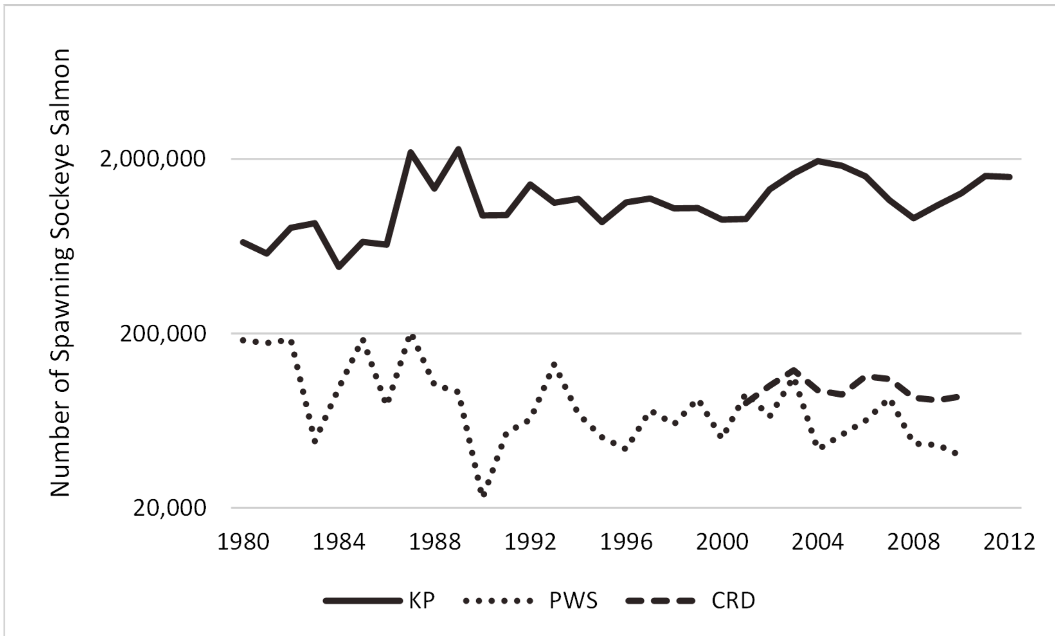


Figure 6. Estimated number of sockeye salmon spawning in key sockeye/coho salmon aquatic ecosystem watersheds from 1980 to 2012 for the geographic areas (Botz, Sheridan, Weise, Scannell, Brenner, & Moffitt, 2013; Shields & Dupuis, 2012).

Trends in fish abundance; pink/chum salmon aquatic ecosystems

As described previously, of the 254 Chugach National Forest stream systems that were assigned to the pink/chum salmon aquatic ecosystem classification, all but four occur within Prince William Sound (see table 14). While fish abundance data is lacking for this aquatic ecosystem in the Kenai Peninsula and Copper River Delta, within the Prince William Sound area, run-size information is robust with comprehensive accounting of both spawner escapement and fishery harvest across most of the production area (Botz, Sheridan, Weise, Scannell, Brenner, & Moffitt, 2013). For the past 50 years, the number of wild pink salmon produced in Prince William Sound fluctuated around an average of about 10 million fish. During this period, there has been no long term pattern of decline or increase (see figure 7). Since the late 1990s, there has been a large number of hatchery produced pink salmon returning to Prince William Sound. An intensive effort by ADF&G to estimate hatchery and wild fish in the fisheries and on the spawning grounds has made it possible to estimate how many pink and chum salmon were produced in the wild after the hatchery operations started in the late 1980s. This effort made it possible to assess the run-size pattern for naturally produced wild fish for a long continuous period.

The information for wild chum salmon in Prince William Sound was used to document that the average run size since 1970 has been in the range of 1 million fish (an order of magnitude less than for the pink salmon). There does not appear to be a long-term trend in the chum run-size during the last 40 years, although considerable variation occurred within this time period (see figure 7).

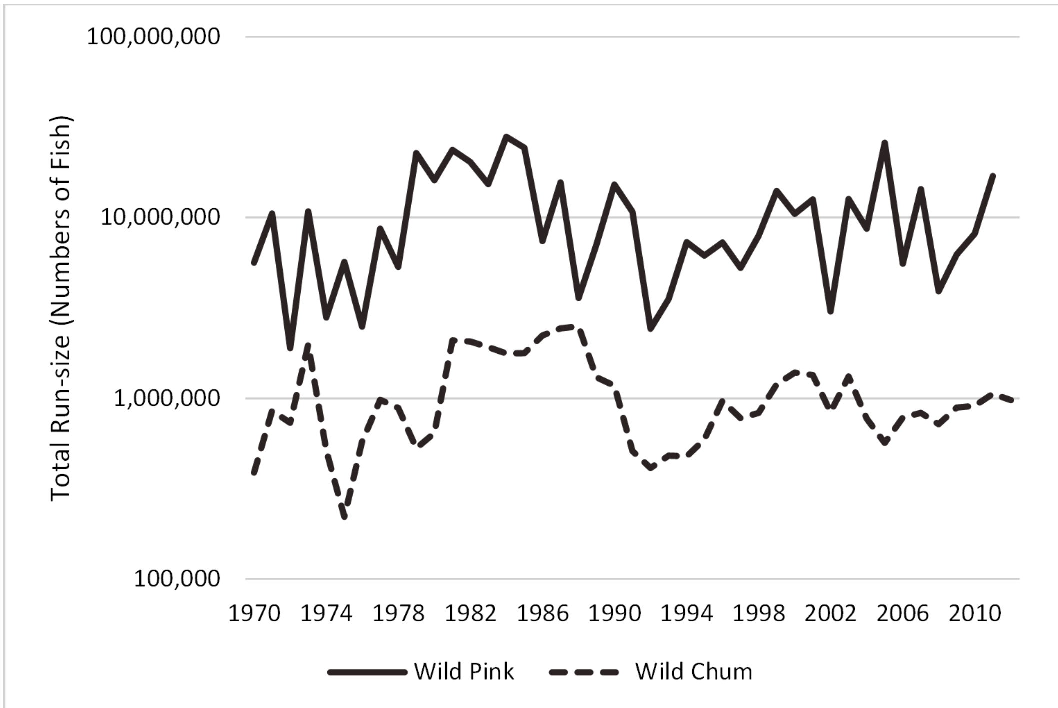


Figure 7. Total run-size (fishery harvest plus spawner escapement) of wild pink salmon and wild chum salmon based on ADF&G data collected from 1960 to 2011 (Botz, Sheridan, Weise, Scannell, Brenner, & Moffitt, 2013).

The run-size pattern for pink and chum salmon both seem to reflect a cyclical behavior. To better visualize this, annual data were combined into a series of five-year moving averages. This smoothed out some of the annual variation and established the presence to two similar cycles of fish production (see figure 8).

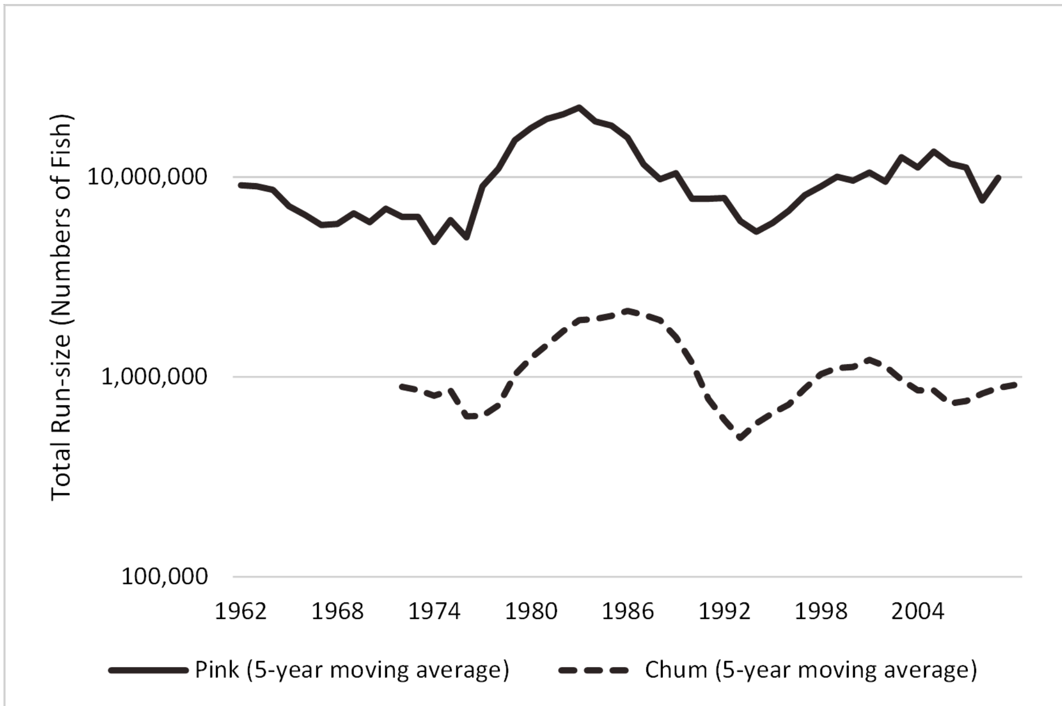


Figure 8. Total run-size of wild pink salmon and wild chum salmon expressed as a five-year moving average of annual run size estimates from 1960 to 2011 (Botz, Sheridan, Weise, Scannell, Brenner, & Moffitt, 2013).

Trends in fish abundance; Dolly Varden char aquatic ecosystems

Dolly Varden char fishery data (catch and harvest) were used to assess the population trends for the primary species of this aquatic ecosystem (Begich & Pawluk, 2011; Hochhalter, Blain, & Failor, 2011). Fishery catch for the upper Kenai River from Skilak Lake to Kenai Lake (Kenai Peninsula) has trended strongly upward during the past 20 years with catches ranging from 20,000 fish per year to upwards of 100,000 fish per year currently (see figure 9).

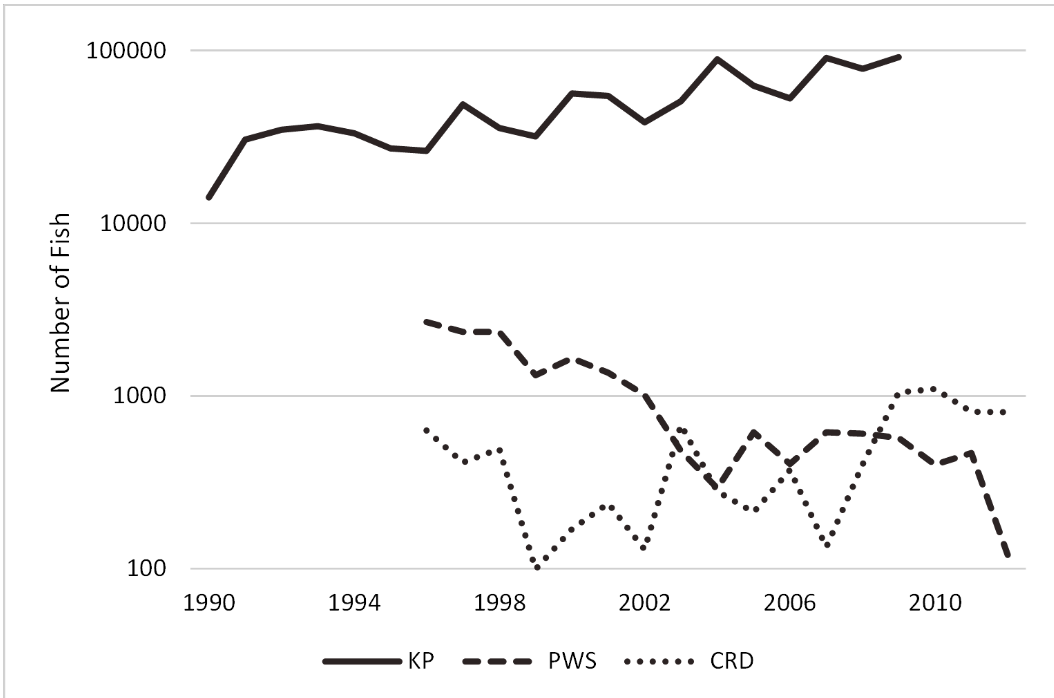


Figure 9. Summary of ADF&G catch information for Dolly Varden char in upper Kenai River (between Skilak and Kenai lakes) from 1984 to 2009, number of Dolly Varden char harvested in representative streams for the Prince William Sound and Copper River Delta from 1996 to 2012 (Begich & Pawluk, 2011; Hochhalter, Blain, & Failor, 2011).

An interesting feature of the upper Kenai River fishery is that less than one percent of the Dolly Varden char caught are retained by anglers as harvest (Begich & Pawluk, 2011), effectively making it a catch and release fishery.

There are no comparable Dolly Varden char fishery data for Prince William Sound and the Copper River Delta. What is available are estimates of fishery harvest only, unlike the case for the Kenai Peninsula where estimates for both the number of fish caught and kept (harvest) and the number of fish that are caught and released exists. For Prince William Sound, fishery harvest of Dolly Varden char appears to have declined from 1996 to 2012. Similar harvest data for the Copper River Delta streams do not show any clear trend up or down.

Another problem with data from the geographic areas is that they are obtained in locations where the Dolly Varden char caught may be anadromous (sea-run), rather than the resident form. Therefore, the trends shown here (see figure 9) may or may not be representative of the conditions for non-anadromous zones associated with the Dolly Varden char aquatic ecosystem described in this assessment.

Although, the Dolly Varden char in the upper Kenai River from the outlet at Kenai Lake downstream to where it enters Skilak Lake may be both resident and anadromous forms, the rainbow trout in this same reach of the Kenai River are believed to be entirely resident (Begich & Pawluk, 2011). The catch of rainbow trout in this river section (as reported by Begich and Pawluk 2011) shows a strong upward trend. The nature of the fishery is similar too, with less than one percent of the fish caught actually being kept and harvested (see figure 10). Together, the catch of Dolly Varden char and rainbow trout in this portion of the Kenai River is approaching 200,000 fish per year.

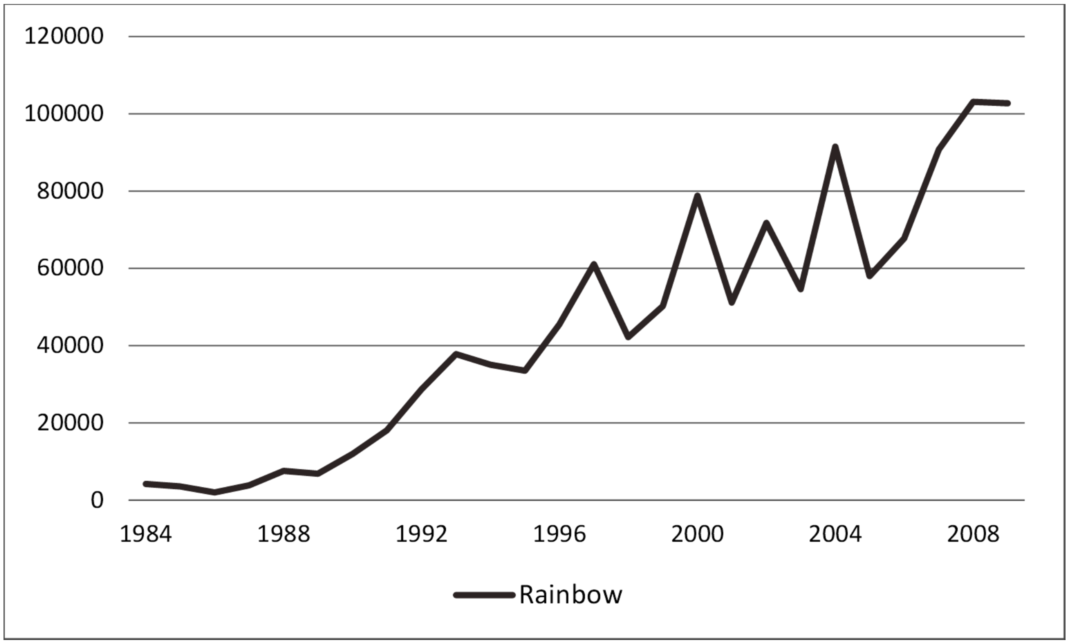


Figure 10. Catch of rainbow trout in upper Kenai River (between Skilak and Kenai Lakes) from 1984 to 2009 (Begich & Pawluk, 2011).

Hatchery impact on natural production

The potential for interactions between hatchery fish and wild fish within the Chugach National Forest is very low for the Copper River Delta and most of the Kenai Peninsula. The exceptions are the Salmon Creek watershed in the southeast portion in the Kenai Peninsula and much of the Prince William Sound. For the Salmon Creek watershed (Kenai Peninsula), specific measurements of the level of hatchery fish mixing with natural populations of coho, Chinook, and sockeye are unavailable; however, based on the size of the hatchery program, it is possible the mixture rate is high (USDA, 2011c).

For Prince William Sound, hatchery fish have been present since the late 1980s, when large-scale production of hatchery pink and chum salmon was initiated. The fish that return from this hatchery production releases are caught in associated fisheries and are important to the local economies. Hatchery fish that are not caught either return to their release point at a hatchery or stray into nearby natural spawning areas and mix with wild fish.

ADF&G biologists are monitoring and assessing the rate of mixing between hatchery and wild fish in Prince William Sound. Based on a model, Brenner et al. (2012) found that across all pink salmon populations the potential impact of stray hatchery fish is greatest in the southwestern portion of Prince William Sound and in the vicinity of the primary pink salmon hatcheries. Only in one-quarter of the streams were hatchery strays predicted to comprise 5 percent or less of the naturally spawning population. Hatchery strays would exceed 10 percent of the spawning population in nearly 39 percent of the streams with pink salmon.

To conserve the long-term genetic character and productivity of natural populations, several authors have suggested that stray hatchery fish should comprise no more than 5 to 10 percent of the spawning population (Ford, 2002; Mobrand, et al., 2005).

Hatchery-origin chum salmon are also known to stray into natural spawning areas within Prince William Sound. However, the fraction of these strays in natural chum populations is known for only a relatively small number of stream systems. Of the 25 locations examined in Prince William Sound during a four-year period, Brenner et al. (2012) found that the incidence of stray hatchery fish was 5 percent or greater for about half of the locations. Although the number of streams sampled may be too few to be representative of Prince William Sound in general, it appears that the level of hatchery fish in naturally spawning chum salmon populations may be higher in the southwestern portion of Prince William Sound.

Climate change

As reported in the Climate Change section of this chapter, the Climate Change Vulnerability Assessment effort estimated that 10 percent of the watersheds in the Chugach National Forest would be vulnerable to climate change. In all cases, this consisted of a watershed transitioning from a snow dominated form of precipitation to a transitional snow type category, characterized by more rain and less snow. It was assumed these vulnerable watersheds would be in locations where the aquatic ecosystem may be stressed in the future.

The Climate Change Vulnerability Assessment effort estimates that during the next 50 years that the pink salmon population may benefit from the rate of warming expected, with a possible production increase of 26 percent. For chum salmon, a model-based decrease of up to 41 percent production was estimated. However, this estimate was not a statistically significant possibility because the number of populations (16) involved in the estimate is too few given the range of variation in response among the different populations.

Abdul-Aziz et al. (2011) examined 18 global climate models' sea surface temperature simulation outputs to develop seasonal high-seas thermal habitats for six species of Pacific salmon. Their results for pink salmon and chum salmon indicate that the populations of these species may very well decline in the Gulf of Alaska, a result of substantial reductions of historical habitat. Any observed increases in production of both species may be due to a compensation for the southern habitat losses from the shift of the warm water boundaries by the 2040s and 2080s and by habitat gains in adjacent seas due to the northward movement of cold water boundaries.

Aquatic Ecosystem Integrity

In this evaluation, information about living organisms (salmon and char) is used as tools to evaluate the condition of the five aquatic ecosystems distributed across the Chugach National Forest. The measureable elements considered were trends in fish abundance (present), potential impact of hatchery fish (present and future), and climate change (present and future). In presenting these findings, a numerical rating system for each assessment element with possible values from negative 2.0 (very adverse condition) to 2.0 (very robust condition) for each geographic area was used. Using the number of stream systems classified into each geographic area as weights, an overall score for each element was computed (i.e., trend, hatchery fish, and climate change). A score was assigned to each element for information uncertainty ranging from 0.5 for relatively certain to 2.0 for highly uncertain. Element scores (for trend, hatchery fish, and climate change) were averaged to obtain an overall condition rating for the aquatic ecosystem. The uncertainty scores were also averaged as an index of overall uncertainty in the aquatic ecosystem rating.

In viewing the results based on this scoring system, it is emphasized that the values obtained should be considered relative indices of aquatic ecosystem condition and not absolute measures. They are best used to describe the condition of the five aquatic ecosystems relative to each other. They are not well suited for making an absolute statement about the degree of aquatic ecosystem integrity. It is also emphasized that, although the uncertainty scores associated with each aquatic ecosystem index value are qualitatively based, they are a critically important element of the aquatic ecosystem assessment and should receive at least equal focus.

Chinook salmon aquatic ecosystem (net score -0.44)

This aquatic ecosystem is most common in the Kenai Peninsula and the index for the condition of this area is the early and late runs of Chinook returning to the Kenai River. In recent years, the declines in both of these populations have been substantial and have reached previously unrecorded low levels. A negative 2.0 score was assigned for Kenai Peninsula Chinook salmon. For Prince William Sound and Copper River Delta, scores of 1.0 and negative 1.0, respectively, were assigned. The impact of hatchery fish is likely negligible across all areas as is the impact of climate change; however, there is a high degree of uncertainty in the assessment concerning the climate change impacts (see table 15).

Table 15. Indices of relative aquatic ecosystem integrity and associated uncertainty for Chugach National Forest stream systems classified as belonging to the Chinook salmon aquatic ecosystem

Evaluation Elements	Geographic Area (Number of Stream Systems)			Index Score	Uncertainty Score
	Copper River Delta (4)	Kenai Peninsula (16)	Prince William Sound (4)		
Population trends	-1.0	-2.0	+1.0	-1.33	1.0
Hatchery impacts	0	0	0	0.00	0.5
Climate change	0	0	0	0.00	2.0
Combined				-0.44	1.17

Coho salmon aquatic ecosystem (net score 0.09)

Sport fishery catch of coho salmon was used as the primary indicator of trend for this aquatic ecosystem. Based on the strongly upward trend for Copper River Delta data, a trend score of 2.0 was assigned (see table 16). The score of zero for Kenai Peninsula and Prince William Sound reflected the lack of any trend in the data. However, watershed specific information on spawner numbers is lacking in nearly all areas. The uncertainty score of 2.0 for the trend scores reflects this data shortcoming. The impacts of hatchery fish and climate change are likely minor throughout most of the coho aquatic ecosystem watersheds. However, there is a high degree of uncertainty as the data necessary to assess such impacts is limited to only a few locations, which may or may not be representative of the whole. Hatchery coho salmon are more common in watersheds with lakes and therefore associated with the sockeye/coho salmon aquatic ecosystem classification, which is presented next.

Table 16. Indices of relative aquatic ecosystem integrity and associated uncertainty for Chugach National Forest stream systems classified as belonging to the coho salmon aquatic ecosystem

Evaluation Elements	Geographic Area (Number of Stream Systems)			Index Score	Uncertainty Score
	Copper River Delta (8)	Kenai Peninsula (4)	Prince William Sound (45)		
Population trends	+2.0	0	0	0.28	2.0
Hatchery impacts	0	0	0	0.00	1.0
Climate change	0	0	0	0.00	2.0
Combined				0.09	1.67

Sockeye/coho salmon aquatic ecosystem (net score -0.15)

Lakes or lake-like habitat is a typical feature of watersheds that contain both sockeye and coho salmon assigned to this aquatic ecosystem. A score of 1.0 was assigned to Kenai Peninsula stream systems because of an upward trend in sockeye salmon abundance and neutral trend for coho salmon (see table

17). Impacts of hatchery fish are possible in Prince William Sound and the Kenai Peninsula for both species as is reflected in the scoring (see table 17). For the Kenai Peninsula, these impacts do not occur in the Kenai River system, which is the primary fish producer of the area, but may be a factor in the Salmon Creek system (near Seward), and the possibility of hatchery coho salmon straying into the streams of Turnagain Arm (near Portage) exists. Lakes that are typical for the stream systems of this aquatic ecosystem are expected to cushion some of the impacts from climate change on water temperatures and stream flow. There is also some indication that sockeye populations in Prince William Sound may benefit from temperature changes expected with climate change. The scoring for climate change (0.44) reflects this possibility, although the uncertainty remains high because the data needed to perform this analysis is limited to a few stream systems.

Table 17. Indices of relative aquatic ecosystem integrity and associated uncertainty for Chugach National Forest stream systems classified as belonging to the sockeye/coho salmon aquatic ecosystem

Evaluation Elements	Geographic Area (Number of Stream Systems)			Index Score	Uncertainty Score
	Copper River Delta (26)	Kenai Peninsula (13)	Prince William Sound (31)		
Population trends	0	1.0	-1.0	-0.26	1.0
Hatchery impacts	0	-1.0	-1.0	-0.63	1.0
Climate change	0	0	1.0	0.44	2.0
Combined				-0.15	1.33

Pink/chum salmon aquatic ecosystem (net score -0.33)

For the pink/chum salmon aquatic ecosystem, the detail of information on fish abundance (in fisheries and on the spawning grounds) is excellent for Prince William Sound, especially for pink salmon. Although comparable information for the Kenai Peninsula and Copper River Delta is limited, this is not a major assessment problem since all but 4 of the 254 stream systems classified into the pink/chum salmon aquatic ecosystem occur in Prince William Sound (see table 18).

The score for hatchery impacts of negative 1.0 reflects the fact that hatchery fish stray into many natural production areas and may impact the genetic diversity and resilience of wild pink and chum salmon populations within Prince William Sound (see table 18). It appears that pink salmon populations may benefit from the warmer temperatures expected as a result of climate change; however, the opposite may be true for chum salmon. In addition, pink/chum salmon aquatic ecosystem watersheds appear to be more vulnerable to climate change. In light of this information, a net score of zero was assigned to this assessment element (see table 18).

Table 18. Indices of relative aquatic ecosystem integrity and associated uncertainty for Chugach National Forest stream systems classified as belonging to the pink/chum salmon aquatic ecosystem

Evaluation Elements	Geographic Area (Number of Stream Systems)			Index Score	Uncertainty Score
	Copper River Delta (3)	Kenai Peninsula (1)	Prince William Sound (250)		
Population trends	0	0	0	0.00	0.5
Hatchery impacts	0	0	-1.0	-0.98	0.5
Climate change	0	0	0	0.00	1.0
Combined				-0.33	0.83

Dolly Varden char aquatic ecosystem (net score -0.22)

Little information is available about the distribution and abundance of Dolly Varden char, which is the primary species that represents this aquatic ecosystem. Freshwater catches of Dolly Varden char appear to be declining in Prince William Sound and increasing in the Kenai Peninsula, at least for the upper Kenai River, where catches of resident rainbow trout are increasing as well. A score for this element of negative 0.65 reflects the fact that the majority of stream systems classified into this aquatic ecosystem are within Prince William Sound where trends may be decreasing (see table 19). However, the uncertainty score of 2.0 for the trend element reflects the fact that much of the catch data probably comes from anadromous stream portions and therefore are not representative of this aquatic ecosystem, which occurs only in non-anadromous waters. The impacts of climate change on this aquatic ecosystem are not clearly negative or positive.

Table 19. Indices of relative aquatic ecosystem integrity and associated uncertainty for Chugach National Forest stream systems classified as belonging to the Dolly Varden char aquatic ecosystem

Evaluation Elements	Geographic Area (Number of Stream Systems)			Index Score	Uncertainty Score
	Copper River Delta (20)	Kenai Peninsula (17)	Prince William Sound (165)		
Population trends	0	+2.0	-1.0	-0.65	2.0
Hatchery impacts	0	0	0	0.00	1.0
Climate change	0	0	0	0.00	2.0
Combined				-0.22	1.67

Summary

Among the five aquatic ecosystems, the condition of the Chinook salmon aquatic ecosystem had the lowest rating, while the coho salmon aquatic ecosystem had the highest rating (see figure 11). As noted earlier, these index scores are best used as a means to make relative comparison among the five aquatic ecosystems evaluated. They are not well suited as a measurement of absolute aquatic ecosystem integrity.

Finally, there is a great deal of uncertainty in accuracy of the aquatic ecosystem condition scores presented here. Using professional judgment, the uncertainty is characterized as low, medium, or high with assigned numerical values of 0.5, 1.0, and 2.0, respectively. These values were combined to obtain a single uncertainty rating for each aquatic ecosystem. By adding and subtracting each uncertainty rating with its respective aquatic ecosystem condition score, an upper and lower bounds of possible scores was generated as illustrated in figure 11. It may or may not be appropriate to calculate possible ranges for aquatic ecosystem condition in this manner. However, as a relative comparison of ranges among the five aquatic ecosystems, it provides useful insight. The amount and quality of information for Pink/chum salmon aquatic ecosystem is superior among the five and this is reflected in a relatively narrow range of possible condition scores. In contrast, the information for the coho salmon and Dolly Varden char aquatic ecosystems is marginal and this is reflected in a much wider spread of possible condition scores. It is also important to note that while the point values for the aquatic ecosystem integrity index differ among the five aquatic ecosystems this difference is minimal compared to the range of possible values generated by the uncertainty assumed to be associated with these estimates.

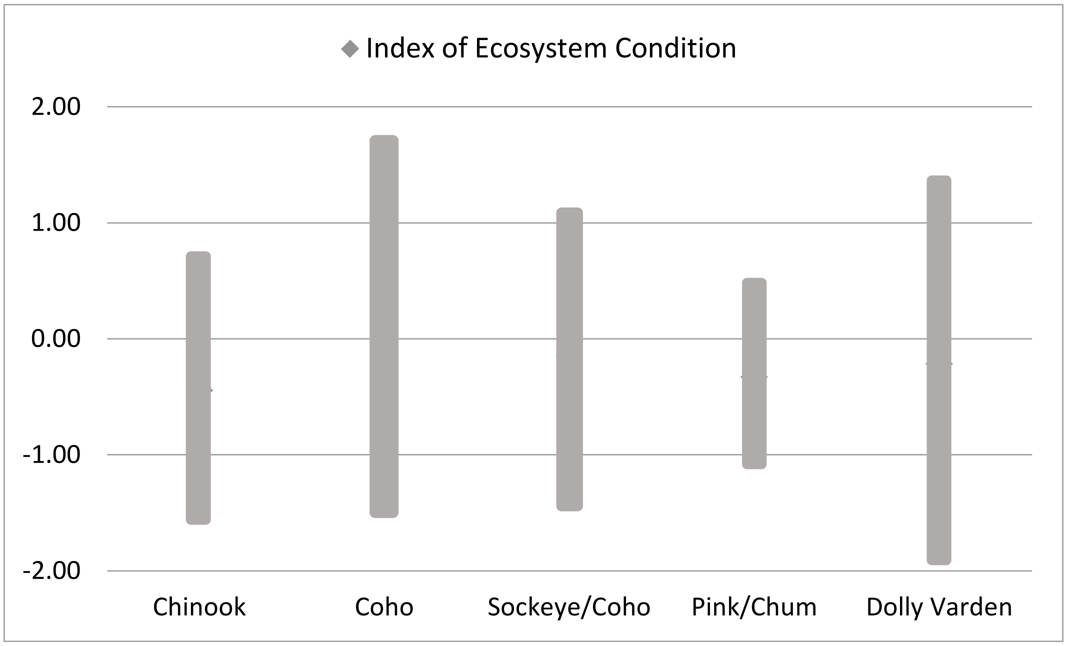


Figure 11. Overall aquatic ecosystem condition index scores (solid diamonds) and associated range of possible values representing scoring uncertainty (vertical bars) for five aquatic ecosystems that occur within the Chugach National Forest

Information Needs

This evaluation of Chugach National Forest aquatic ecosystems was limited by the lack of information and findings from relevant analyses. Many of these limitations could be overcome if the following list of information-based actions is undertaken.

- Existing and additional aquatic habitat data need to be developed in a manner that will inform key aquatic ecosystem characteristics of the Chugach National Forest. This would require a comprehensive inventory of aquatic habitat that is specifically structured to address the production of key, economically important species (e.g., salmon).
- Long-term fish monitoring across the Chugach National Forest is needed to successfully assess aquatic ecosystem trends. Working with other state and Federal fishery resource management partners, a means to cooperatively develop and maintain long-term data sets, is needed.
- In recent years, Chinook salmon returning to the Kenai River have declined to the lowest levels ever recorded. Information is needed to provide a better understanding of how Chinook salmon use the aquatic habitat in the upper Kenai watershed.

In areas where there is heavy fishing pressure, human foot traffic can seriously damage riparian habitat and adversely impact the condition of the aquatic ecosystem. The severely damaged riparian habitat alongside the Russian River that has since been repaired is one example of this problem. There is no systematic survey or inventory of popular fishing areas to assess whether similar damage is occurring elsewhere. Should such an inventory be developed, not only would it help evaluate the aquatic ecosystem condition, it would also identify possible locations for future restoration and monitoring opportunities.

Aquatic Ecosystems—Riparian Areas and Wetlands

This section describes the riparian and wetland ecosystem evaluation. Specific items evaluated include key ecosystem characteristics by geographic area, drivers and stressors, and riparian and wetland condition and trends. This section also uses the national assessment approach from the Watershed Condition Framework (WCF) and the Forest Service Watershed Condition Classification (WCC) Technical Guide (Potyondy & Geier, 2010) to evaluate riparian and wetland conditions across the national forest. Ecosystem integrity is evaluated as well, and the remaining information needs are provided.

Relevant Information

- There are several recreation developments that are within riparian areas. Recent floods (September 2012) and historic floods have eroded existing recreational developments (e.g. campsites and picnic areas) located within or adjacent to riparian areas. These types of sites should be given priority when seeking to restore riparian and floodplain function.
- The majority of the riparian areas within the Chugach National Forest are in good condition (Class 1). Impacts to riparian and wetland vegetation within the national forest are limited and localized. These impacts primarily occur along roads, in places where fuelwood harvest and large scale mining have occurred, in high recreational use areas (i.e., along the Russian River), and in areas affected by spruce bark beetles. A number of watershed restoration projects have occurred since 2002 to improve the functions of streams and riparian areas in various portions of the national forest.
- An integrated riparian mapping GIS layer does not exist for the national forest. Such a layer would be beneficial for planning and managing development activities in these areas across the national forest.
- Recreational gold mining activities are damaging riparian integrity. Standards and guidelines could be strengthened to reduce riparian resource damage. The locations where recreational gold mining are allowed or encouraged could also be re-examined.

Ecosystems Being Evaluated

Riparian areas are the interface between terrestrial and aquatic ecosystems and are an integral part of watersheds. Riparian ecosystems are characterized by the presence of trees, shrubs, or herbaceous vegetation that require free or unbound water or conditions that are moister than surrounding areas. Typical examples include floodplains, streambanks, lakeshores, tidal flats and sloughs, saltwater marshes, estuaries, freshwater ponds, marshes, bogs, muskegs, and forested wetlands. Riparian ecosystems are generally inclusive of wetlands.

Properly functioning riparian and wetland areas improve water quality, reduce erosion, filter sediment, capture bedload, stabilize streambanks, and act as a sink for atmospheric carbon. Riparian vegetation is a source of nourishment for many animals, from insects to mammals, including the organic matter that is an important source of nourishment to aquatic organisms. It also aids in providing leaf litter and terrestrial invertebrates to streams. Additionally, healthy riparian and wetland areas provide diverse habitats for fish, wildlife, waterfowl, and other species, many of which are obligates to this ecosystem for all or part of their life cycle. Riparian areas also provide travel corridors for wildlife, refugia for some species, and can provide essential temperature moderation.

Riparian areas are typified by continual change and periodic major disturbances from flooding, channel sinuosity, erosion, and periods of anaerobic submersion. Organisms within the riparian zone have special adaptations to respond to these changing and challenging conditions and some, such as beavers, may have a profound influence on the hydrology, and species composition within riparian zones.

An important ecological benefit of riparian areas is the production and input of wood into aquatic systems in rivers. Large woody debris in streams dissipates energy, stabilizes streambanks and captures sediment and nutrients. It also provides refugia for instream plants, fish, animals and aquatic insects; increases habitat complexity; and serves as unique microhabitats for species that use down wood components, including important arthropods that feed salmon and birds.

Within the Chugach National Forest, it is often hard to distinguish where riparian ecosystems differ from other forest vegetation. Riparian ecosystems are more easily delineated in regions with limited water availability. However, water (precipitation) is generally very abundant within the Chugach National Forest. Generally, annual precipitation (P) exceeds vegetation water losses to potential evapotranspiration (PET); however, some studies on the Kenai Peninsula have documented recent changes and accelerated losses of wetlands (drying habitats) associated with increased evapotranspiration as a direct result of increased mean summer temperatures since the 1970s (Berg, Henry, Fastie, DeVolder, & Matsuoka, 2006; Berg, Hillman, Dial, & DeRuwe, 2009; Klein, Berg, & Dial, 2005).

High water availability within the national forest also results in a great abundance and variety of wetlands. Wetlands are defined in the 1987 Corps of Engineers Wetlands Delineation Manual (US DOD, 1989): "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, bogs, and similar areas." The U.S. Fish and Wildlife Service has completed wetlands mapping of all of the Chugach National Forest and portions of the rest of Alaska. Approximately 1.44 million acres of the national forest is classified as wetland.

Total wetlands as inventoried by the National Wetlands Inventory using the Cowardin system (Cowardin, 1979) cover about 23 percent of the national forest. More than half of these wetlands are in the Copper River Delta geographic area. The Copper River Delta is the largest contiguous wetland on the Pacific coast of North America. There are 700,000 acres of wetlands plus associated uplands, and the area is a two million acre management unit that provides important fish and wildlife habitat. The Copper River Delta is recognized worldwide as an important conservation area. The complex riverine channels of the Copper River Delta provide spawning and rearing habitat for all five Pacific salmon species. In addition, some of the northernmost populations of cutthroat trout occur in the numerous small, clear-water streams. Nearly the entire world's population of western sandpiper and Pacific dunlin use this area as a stopover site during spring migration. Six to 10 percent of the world's trumpeter swan population nests on the Copper River Delta. Fifty to 70 percent of all Tule white-fronted geese stage here in the fall. One hundred percent of the world's dusky Canada geese nest here. More than 10 million waterfowl and shorebirds use it as either a staging or breeding area. The Copper River Delta is the largest Forest Service managed Alaska key coastal wetland. The ecosystem services, natural capital, and fish and wildlife resources that this wetland provides is recognized by the Forest Service and by national and international agencies. See also Terrestrial Ecosystems—Wildlife.

Table 20 displays mapped wetlands by system type within the national forest administrative boundary and for each geographic area. Estuarine wetlands are generally those in the intertidal zone that have a brackish (part salt water and part fresh water) component. Riverine wetlands include wetlands within fresh water river channels. Lacustrine wetlands are defined as those wetlands and deepwater habitats in lakes deeper than about 6.5 feet and larger than 20 acres. Palustrine wetlands are generally small ponds, upland marshes, bogs, small muskegs and fens, and forested wetlands. Marine wetlands are those along the marine shoreline, including beaches, rocky shores, lagoons, and shallow reefs. Not displayed in this table are subtidal and deepwater estuarine and subtidal and deepwater marine environments.

Table 20. Wetland acres for each system within the Chugach National Forest and each geographic area

Wetland System	Wetland Acres			
	Geographic Areas			National Forest Totals
	Copper River Delta	Kenai Peninsula	Prince William Sound	
Estuarine	159,271	111,777	86,995	**358,042**
Lacustrine	37,582	28,983	28,959	**95,524**
Palustrine	355,834	39,674	367,433	**762,941**
Riverine	176,874	8,927	6,254	**192,054**
Marine	22,221	26	10,251	**32,498**
Totals	**751,782**	**189,386**	**499,891**	**1,441,059**

Data are from the USFWS National Wetlands Inventory and does not include subtidal, deep water, and the fiords of Prince William Sound, which are not managed by the Forest Service. Acreages are based on all lands within the outer boundary of the Chugach National Forest (this includes lands of other ownership within the national forest matrix) (USFWS, 1979).

Key Ecosystem Characteristics

Riparian area and wetland condition was one of the attribute indicators for the WCC assessment. As part of this effort, function and condition of native riparian vegetation along streams, water bodies, and wetlands was evaluated for the Chugach National Forest. Data sources for this analysis include resource specialist knowledge of local riparian conditions, information from various landscape assessments completed between 2000 and 2010, the FACTS GIS database delineating areas of past riparian harvest, Alaska-wide insects GIS database delineating areas of spruce bark beetle infestation, and Chugach National Forest corporate GIS database (legacy water features, streams).

Riparian areas and wetland function and condition were evaluated based on the parameters outlined in the WCC (Potyondy & Geier, 2010). The attributes evaluated include:

- Diverse age-class distribution of native riparian/wetland vegetation (recruitment for maintenance and recovery)
- Diverse composition of native riparian/wetland vegetation (for maintenance and recovery)
- Presence of native species that indicated maintenance of riparian/wetland soil moisture characteristics and connectivity between the riparian/wetland vegetation and the water table typical of riparian/wetland systems in the area
- Streambank native vegetation (with plants or plant communities that have root masses capable of withstanding high streamflow events)
- Native riparian/wetland vegetation adequately covers and protects the banks and dissipates energy during high flows
- Plant vigor: the presence of plant communities that will provide an adequate source of coarse and/or large woody material (for maintenance and recovery)

Based on the condition of these attributes, riparian/wetland areas were then rated into three classes: Class 1 (good, functioning properly); Class 2 (fair, functioning at risk); and Class 3 (poor, functionally impaired) (see table 21).

Table 21. Riparian/wetland vegetation condition rating rule set (Potyondy & Geier, 2010)

Attribute	Riparian/Wetland Vegetation Condition Indicator		
	Class 1 (good, functioning properly)	**Class 2 (fair, functioning at risk)**	**Class 3 (poor, functionally impaired)**
Vegetation condition	Native mid to late seral vegetation appropriate to site potential dominates the plant communities and is vigorous, healthy, and diverse in age, structure, cover and composition on more than 80 percent of the riparian/wetland areas in the watershed. Sufficient reproduction of native species appropriate to the site is occurring to ensure sustainability. Mesic herbaceous plant communities occupy most of their site potential. Vegetation is in dynamic equilibrium appropriate to the stream or wetland system.	Native vegetation demonstrates a moderate loss of vigor, reproduction, and growth, or it changes in composition, especially in areas most susceptible to human impact. Areas displaying light to moderate impact to structure, reproduction, composition, and cover may occupy 25 to 80 percent of the overall riparian area with only a few areas displaying significant impacts. Up to 25 percent of the species cover or composition occurs from early seral species and/or there exist some localized but relatively small areas where early seral vegetation dominates, but the communities across the watershed are still dominated by mid to late seral vegetation. Xeric herbaceous communities exist where water relationships have been altered but they are relatively small and localized, generally are not continuous across large areas, and do not dominate across the watershed.	Native vegetation is vigorous, healthy, and diverse in age, structure, cover, and composition on less than 25 percent of the riparian/wetland areas in the watershed. Native vegetation demonstrates a noticeable loss of vigor, reproduction, growth, and changes in composition as compared to the site's potential communities throughout the area most susceptible to human impact. In these areas, cover and composition are strongly reflective of early seral species dominance although late- and mid-seral species will be present, especially in pockets. Mesic-dependent herbaceous vegetation is limited in extent with many lower terraces dominated by xeric species most commonly associated with uplands. Reproduction of mid and late seral species is very limited. For much of the area, the water table is disconnected from the riparian area and the vegetation reflects loss of available soil water.

Drivers and Stressors

The primary system drivers and stressors to riparian and wetland areas include increased population and/or national forest use, potential decreased salmon stocks, glacial retreat, earthquakes and the anticipated overarching effects of climate change.

Impacts to riparian and wetland areas from increased population and/or national forest use could include increased placer mining, gravel extraction and development, increased water storage or diversions (hydroelectric facilities), new road construction, increased recreational use (particularly OHV use and angler developed trails), and the potential for increased introduction of invasive species (both terrestrial and aquatic) (Haufler, Mehl, & Yeats, 2010). Overall, human activity tends to concentrate in riparian areas. Riparian areas offer scenic qualities, fishing and trapping opportunities, flatter topography (on lower reaches) and the potential of travel (boats, float planes). Riparian areas within the Chugach National Forest have few impacts due to reduced access, steep topography and high gradient stream systems. Lower reaches of some major waterways are bounded by roads, railroads, and trails in localized areas where access is easier; there impacts to riparian areas are more prevalent.

Potential decreases in salmon stocks may also reduce the productivity of riparian ecosystems. Spawning Pacific salmon contribute marine-derived nutrients to riparian ecosystems, which fertilize and enhance riparian production (Bartz & Naiman, 2005; Gende, Miller, & Hood, 2007; Helfield & Naiman, 2001). A decrease in these ocean derived nutrients may decrease the health and vigor of riparian vegetation over time.

Earthquakes may also play a role as a system driver and stressor for wetlands by changing water table elevations. The 1964 earthquake profoundly affected wetlands across the Chugach National Forest. Tectonic subsidence in some areas, such as Cook Inlet and parts of eastern Prince William Sound, resulted in locally elevated ocean levels introducing saltwater to freshwater ecosystems. Conversely, in areas of tectonic uplift, such as the Copper River Delta and most of Prince William Sound, previous saltwater influenced wetlands converted to freshwater. The earthquake also drained 700,000 acres of wetlands in a matter of minutes (Kuntzsch, personal communication, 2014). Wetlands in these affected areas of earthquake uplift and subsidence will be adapting for the next 200 to 400 years. The change from productive saltwater marshes to less productive freshwater systems has had impacts on vegetation and wildlife, most notably the dusky Canada goose (see At Risk Species—Potential Species of Conservation Concern section).

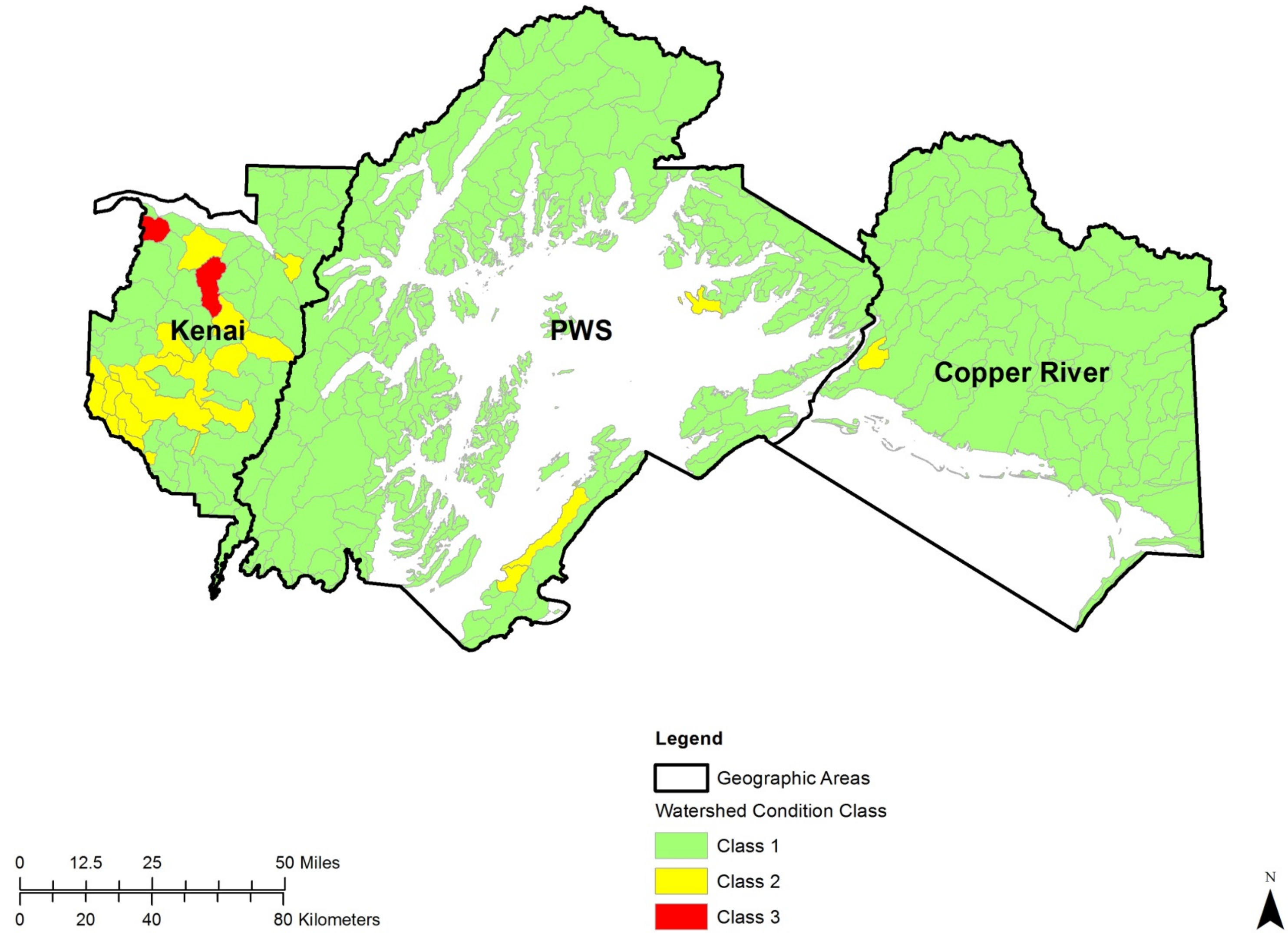
Impacts to riparian and wetland areas from climate change are discussed in the Climate Change section.

Condition and Trends

The Forest Service classified riparian area and wetland conditions for 275 HUC 6 watersheds as part of the WCF using the process outlined in the WCC. The results of the WCC for riparian and wetland condition ratings for the Chugach National Forest are displayed in table 22 and map 4.

Table 22. Riparian and wetland condition ratings for the Chugach National Forest (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Rating	Watersheds
Class 1 (good, functioning properly)	253
Class 2 (fair, functioning at risk)	20
Class 3 (poor, functionally impaired)	2



Map 4. Chugach National Forest watersheds with riparian and wetland impacts by WCC.

Table 23 displays the detailed results of the WCC. Overall, national forest riparian area and wetland conditions are good and functioning properly. The majority of riparian and wetland areas within the Chugach National Forest are unmanaged and not developed. Impacts to riparian area and wetland vegetation are limited. These impacts primarily occur along roads, in OHV use areas, in places where timber harvest and large scale mining have occurred, in high recreational use areas (i.e., Russian River), and in areas affected by the spruce bark beetle infestation during the 1990s. More than 80 percent of the riparian/wetland impacted watersheds within the national forest are on the Kenai Peninsula where human population and use is greater and the effects of spruce bark beetle is more common.

Placer mining within the national forest is generally located within riparian areas. Placer mining activity can involve removing riparian vegetation and processing the gravel substrates found within these riparian areas. Placer mining activities have led to heavy sediment loads in the stream channels, loss of vegetation and soil, and in some cases alteration of stream channel and flood plain function. Streams within the national forest particularly affected by placer mining activities include Resurrection Creek and its tributary Palmer Creek, Bear, Sixmile, Mills, Juneau, Canyon, Cooper, Bertha, Lynx, Silvertip, Gulch, Quartz, and Falls creeks (near Crown Point). Lower Resurrection Creek is impacted by historic and ongoing large scale placer mining activities. Although stream and riparian restoration was conducted on one mile of Resurrection Creek in 2005 and 2006, the vegetation in this reach will take a number of years before it reaches maturity and is able to function naturally. Similar impacts from historic mining have occurred on Cooper Creek.

Recreational gold panning and suction dredging activities also occur within riparian areas. These operations are only authorized to occur within active stream channels, unvegetated abandoned stream beds or unvegetated gravel bars. However, certain systems such as Resurrection Creek and Six-mile Creek, where recreational mining is encouraged (Huber & Kurtak, 2010), are exhibiting mining that extends into the vegetated stream banks causing damage to riparian function and integrity. For instance, in Resurrection Creek, the stream channel has widened up to 20 feet due to a loss of stream banks from these activities. Standards and guidelines could be strengthened to reduce riparian resource damage. The locations where recreational gold mining is allowed or encouraged could also be re-examined.

Past timber harvest on recently acquired lands in Prince William Sound has impacted riparian vegetation where riparian buffers were not adequate (areas on Knowles Head Peninsula and Montague Island). This riparian harvest has resulted in a reduction of large woody debris recruitment into streams, which affects channel form, nutrient inputs, cover, and habitat complexity, as well as riparian vegetation diversity. Habitat complexity and diversity is important for wildlife, birds, fish, and invertebrates. The spruce bark beetle infestation of the 1990s has impacted numerous riparian spruce forests on the Kenai Peninsula and reduced streamside spruce cover. These impacts include loss of riparian vigor, reproduction, and growth, as well as changes in composition. Mortality of spruce has resulted in short-term increases in large woody debris to streams. In the long-term, these areas will have limited large woody debris recruitment and loss of streamside shading.

Roads and trails have impacted riparian and wetland areas where they are located immediately adjacent to streams or water bodies. Their effects include contributions of road derived pollutants, introduction of invasive species, barriers to movement for both terrestrial and aquatic species and loss of wetland connectivity. Some, such as the Seward Highway and the Alaska Railroad, have changed the flow of water in and out of wetlands to the extent that they have converted some estuarine habitats into freshwater habitats resulting in changed riparian vegetation and wetland communities. Wetland damage, such as compaction, erosion, loss of vegetation, and creation of seedbeds for invasive species, also exists from

OHV use on unauthorized trails (user created), particularly on the Copper River Delta and on Hawkins and Hinchinbrook islands.

Table 23. Attribute rankings for the Riparian/Wetland Vegetation indicator within the Chugach National Forest (MacFarlane, Zemke, Kelly, Hodges, & DeVelice, 2011)

Geographic Area	HUC	Watershed Name	Rating*	Comments
Copper River Delta	190201041604	Eyak Lake	2	Roads and development impact riparian vegetation along Eyak Lake and Eyak River.
Kenai Peninsula	190203020304	Portage Creek	2	Much of Portage Creek riparian corridor impacted by highway, railroad, and gravel extraction.
	190203020404	Bench Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203020407	East Fork Sixmile Creek	3	Spruce in riparian floodplains heavily impacted by spruce bark beetle, numerous dead trees.
	190203020408	Walker Creek-Sixmile Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203020504	Lower Resurrection Creek	3	Three miles of Resurrection Creek riparian corridor severely impacted by past and present placer mining, 1 mile of 2005-2006 Phase I restored area has not yet reached maturity. Spruce in remaining riparian floodplains impacted by spruce bark beetle, numerous dead trees.
	190203021001	Headwaters Trail Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021003	Outlet Trail Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021007	Trail Lake-Trail River	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021102	Headwaters Quartz Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021104	Outlet Quartz Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021203	Ptarmigan Lake-Ptarmigan Creek	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021205	Kenai Lake	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021402	Cooper Lake	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021403	Stetson Creek-Cooper Creek	2	Lower 1 mile of Cooper Creek riparian corridor impacted by historic placer mining. Spruce impacted by spruce bark beetle.
	190203021404	Headwaters Russian River	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees.
	190203021405	Outlet Russian River	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees, mostly upstream of Lower Russian Lake.
	190203021406	Jean Creek-Kenai River	2	Spruce in riparian floodplain impacted by spruce bark beetle, numerous dead trees. Some impacts to riparian from Sterling Highway proximity.

Geographic Area	HUC	Watershed Name	Rating*	Comments
Prince William Sound	190202011201	Goose Island-Frontal Prince William Sound	2	Knowles Head timber harvest occurred over some riparian and wetland areas and caused some blowdown in riparian area.
	190202020503	Headwaters Resurrection River	2	Spruce in riparian floodplains heavily impacted by spruce bark beetle, numerous dead trees.
	190202030406	Montague Island-Frontal Prince William Sound	2	Timber harvest occurred in the 1960s and 1970s with no buffers on many streams.
	190202030407	Hanning Bay-Frontal Montague Strait	2	Timber harvest occurred in the 1960s and 1970s with no buffers on many streams.

*All watersheds within the Chugach National Forest received a rating of 1 except for those displayed in this table.

Riparian and Wetland Area Integrity

Riparian and wetland area conditions reflect a range of variation from the natural condition (functioning properly) to degraded (severely altered state or impaired). Riparian and wetland areas that are functioning properly exist when adequate native vegetation, landform, or large woody debris is present within its natural range of variation. Riparian and wetland areas exemplify variability and adaptation in their fully functional state. Consistent with stream process group, a functional system will:

- Filter sediment, capture bedload, and aid in floodplain development
- Improve flood-water retention and ground-water recharge
- Develop root masses that stabilize streambanks against cutting action
- Develop diverse ponding and channel characteristics to provide habitat and water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses
- Support greater biodiversity

In general, the greater departure from the natural state, the more impaired the riparian area is likely to be.

Healthy, properly functioning riparian and wetland areas generally exhibit strong integrity, are more resilient to stressors, and have a greater adaptive capacity. It is anticipated that the trend of strong integrity for the 92 percent of Chugach National Forest riparian areas in good condition will continue. Ultimately, it will be important for Forest Service management to maintain and improve habitat complexity and diversity to ensure resilient species.

A number of watershed restoration projects have occurred within the national forest during the last decade. These improvements have included large scale stream and riparian restoration projects (i.e., Resurrection and Daves creeks) and riparian thinning projects (i.e., Hinchinbrook Island and Knowles Head). These projects have improved the functions of streams and riparian areas associated with impacts from past or historic land management and current activities. Continuing to restore these watersheds, riparian areas, and wetlands will sustain and improve integrity.

Impacts to riparian and wetland areas that affect integrity if not addressed through management include:

- Erosion, sedimentation, and wetland damage from OHV routes forestwide
- Erosion, sedimentation, and wetland damage from user trails (foot and OHV) in the Copper River Delta area
- Stress on streambanks along the Russian River, despite management efforts to restore and protect banks
- Increased use and development needs in riparian areas

- Damage from designated and undesignated campsites and outhouses located within riparian areas
- Damage to riparian areas from commercial mining activities
- Damage from recreational gold panning and sluicing operations, such as digging in banks rather than in active channels as currently allowed
- Stress on streambanks associated with increased back country trail use or use by pack animals
- Trash and plastics (see Marine and Terrestrial Garbage and Debris)
- Introduced species through waders, intentional pet release, off-site bait, and organisms that attach to boats, fishing gear, or float planes

Mechanisms are in place to mitigate the impacts and activities that affect stream banks, wetlands, and riparian areas across the national forest. These include best management practices (BMPs), reclamation, and access control. However, in order to better assess potential impacts to riparian areas as described previously, an integrated riparian mapping GIS layer could be developed. Such a layer would be beneficial for planning and managing development activities.

Terrestrial Ecosystems—Soils

This section of the assessment includes a characterization of the status of soil resources and soil quality. Specifically, this section is used to identify and describe available information on soils and sites, current inventories of soil conditions and improvement needs, and important attributes or characteristics of soils and sites that are susceptible to degradation.

Relevant Information

- Other than finalizing the existing soil monitoring protocol, there is no apparent need to change the management direction of the 2002 Forest Plan relating to soil management based on currently available data.

Key Ecosystem Characteristics

Historically, the National Hierarchical Framework of Ecological Units (Cleland, et al., 1997) has been used by the Forest Service as the basis for mapping landscapes, soils, and vegetation. Ecological classification and mapping systems stratify landscapes at multiple scales, thereby providing a better understanding of the arrangement, pattern, and capabilities of ecosystems. Classification and mapping at the landscape scale uses Landtype Association (LTA) levels. Landtype associations depict broad patterns of soil families or subgroups, the potential natural vegetation (PNV) series, and, on occasion, show successional dynamics (Winthers, et al., 2005). The next finer scale of classification and mapping is the land-unit scale, which represents the most detailed levels of the national hierarchy. These are commonly mapped as Landtypes and Landtype Phases. These depict patterns of soil families or series and PNV subseries and plant associations (Winthers, et al., 2005). Most soil resource inventories are mapped at this scale.

These inventories, in combination with other standard GIS resource layers, provide the basis for selecting suitable areas for major kinds of land-use activities, identifying areas that need more intensive investigation, evaluating various land management alternatives, classifying vegetation and habitat, and predicting the effects of a given activity on resource health or condition.

The current inventory of the soil resource was done at the landscape level and mapped as an LTA inventory. Other, more intensive land-unit mapping efforts, including soil surveys, have taken place where management occurs along the road system. These inventory efforts have been completed at different scales of mapping, intensity, and data collection. In some areas where there is little to no field evaluation, the inventory relied on map and aerial photo interpretation. Soils information in these inventories may be outdated and consequently may not follow current Forest Service or National Cooperative Soil Survey (NCSS) protocol or taxonomy. To date, comprehensive forestwide landtype mapping (or soil resource inventory) has not been completed.

The 2002 Forest Plan final environmental impact statement (FEIS) used LTA information to generally describe the soil resources at a very broad scale and describe general processes that affect soil condition and productivity. There are eight reoccurring LTAs within the Chugach National Forest (Davidson, 1998a; Davidson, 1998b). Table 24 displays the acres of these LTAs by geographic area, including all ownerships. A map of LTAs across the national forest is in the map package appendix. General soil characteristics for these LTAs follow:

- *Glaciers and ice fields*: Some surface deposited soil (ice and rocks dominate).
- *Mountain summits*: Shallow coarse textured soil between rock outcrops. These soils are sensitive to disturbance because they are thin and easily displaced.

- *Mountain side slopes*: Medium textured soil with moderate amounts of coarse fragments often with substantial ongoing erosion.
- *Depositional slopes*: Both deep, well drained, medium textured soil with variable amounts of coarse fragments and areas of fine textured soil that pond water and form wetlands.
- *Glacial moraines*: Poorly to well-drained soils with coarse fragments consisting of non-sorted gravel, cobbles, and stones in a moderate to fine textured matrix. Poorly drained and somewhat poorly drained soils can be highly susceptible to compaction due to wetness.
- *Coastal landscapes*: Both deep, excessively drained sand on beaches and dunes exposed to continuous erosion and deep, poorly drained silts on tidal flats.
- *Fluvial valley bottom outwash*: Dominated by deep, stratified soils with rounded coarse fragments. Pond water or wetlands may occur on fine textured soil. High water tables are common.
- *Hills and plateaus*: Both coarse to medium textured soil with 15 to 65 percent coarse fragments and organic soils in basins between hills where the organic material rests on glacial till or bedrock.

Table 24. Distribution of LTAs by geographic areas of the Chugach National Forest (includes all landownership)

LTA Name	Geographic Area						Totals	
	Copper River Delta		Kenai Peninsula		Prince William Sound			
	acres	percent	acres	percent	acres	percent	acres	percent
Glaciers and ice fields	866,462	40.0	147,933	12.0	1,243,188	41.1	**2,257,583**	**35.1**
Mountain summits	196,933	9.1	407,011	32.9	606,713	20.0	**1,210,657**	**18.8**
Mountain side slopes	242,541	11.2	367,319	29.7	519,807	17.2	**1,129,667**	**17.6**
Depositional slopes	33,586	1.6	124,141	10.0	15,030	0.5	**172,757**	**2.7**
Glacial moraines	47,929	2.2	5,237	0.4	8,493	0.3	**61,659**	**1.0**
Coastal landscapes	334,296	15.4	1,513	0.1	9,491	0.3	**345,300**	**5.4**
Fluvial valley bottom outwash	328,240	15.2	45,839	3.7	33,840	1.1	**407,919**	**6.3**
Hills and plateaus	116,451	5.4	137,127	11.1	590,415	19.5	**843,993**	**13.1**
Totals	**2,166,438**	**100.0**	**1,236,120**	**100.0**	**3,026,977**	**100.0**	**6,429,535**	**100.0**

The 2002 Forest Plan FEIS identifies the most productive soils within the national forest as moderately well drained to well-drained with a medium texture. They are found on fluvial valley bottoms and on depositional slopes. Soils on these land types in the Prince William Sound are more productive than those in the Kenai Peninsula because of more moderate temperatures and greater precipitation.

Organic matter/wetlands

Organic layers thicker than 15.7 inches (40 centimeters) are classified as organic soils and are indicative of wetlands. Total wetlands as inventoried by the National Wetlands Inventory using the Cowardin system (Cowardin, 1979) are about 23 percent of the national forest. Wetlands are considered components or inclusions in the LTA mapping and some of the other, more intensive soil resource inventories and are not specifically identified in these inventories.

Soil quality

Soil is a basic component of the environment. Most living things depend on soil for their initial source of nutrients. Soil absorbs and holds nutrient rich water, releasing it at varying rates to supply nutrients for microorganisms and plants that become food sources and habitat for larger animals and people.

The capability of current soil conditions to support the full range of ecosystem functions and human uses can be described as soil quality. The Soil Science Society of America (2013) has defined soil quality as, "The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health." In order to protect soil quality, it is important to recognize that there are numerous kinds of soils and that the properties of a soil affect a wide variety of ecosystems within the Chugach National Forest.

Key soil properties needed to support ecosystem integrity can be impacted by soil disturbance. The 2002 Forest Plan and regional and national directives identified concerns for ground disturbing activities, including those that compact soil and reduce porosity, affect water flow and aeration, displace surface soils, and cause nutrient and organic matter losses. Forestwide, key soil properties related to these potential impacts include bulk density, porosity, presence of forest floor and A horizons, and effective ground cover. Key characteristics of wetlands include hydric soils, hydrophytic vegetation, and wetland hydrology.

Terrestrial Ecosystems—Soils Condition and Trends

The 2002 Forest Plan places disturbance caps on management activities with the goal of maintaining the productivity of the land.

The primary goal of soil management within the national forest is to maintain soil quality. This process includes inventorying soils, vegetation, and landscape characteristics to identify and locate the soils, making interpretations for appropriate Forest Service management activities, and assuring soil recommendations are implemented.

The 2002 Forest Plan, Chief's appeal decision (USDA, 2004b), and subsequent documents (USDA, 2010a) resulted in two monitoring questions related to soils. The questions are:

1. What is the level of ground disturbing activity?
2. What is the effect of off highway vehicle (OHV) use on the soil and vegetation resources?

In 2010, a decision was made to combine the OHV and ground disturbing monitoring into one protocol. The Monitoring Guide for Chugach National Forest Revised Land and Resource Management Plan (USDA, 2011a) identifies monitoring items for evaluating how well the plan is being implemented and the effect on resources. The monitoring question for soil resources became: "Is Forestwide soil quality decreasing over time due to ground disturbing activities (e.g., OHV and snowmachine use, concentrated foot traffic, fuel reduction activities, road and trail construction)?" As of 2014, this soil monitoring protocol was still not finalized.

Soil resource monitoring to evaluate the level of ground disturbing activity was conducted once in 2009. Results indicated that less than one percent of the area surveyed was disturbed and none of it rated as detrimentally disturbed. Effects of OHV use on soils were evaluated in 2008. At that time, several areas within the Copper River Delta were identified in the 2008 Monitoring Report as having increased disturbance levels. No further soil disturbance monitoring has been conducted.

Terrestrial Ecosystems—Vegetation

This section describes the terrestrial ecosystems evaluation for the Chugach National Forest, including vegetation diversity and system drivers and stressors. Conditions and trends are described, ecosystem integrity is assessed, and information needs are identified. See the Terrestrial Ecosystems—Wildlife section for a discussion of the wildlife component of the terrestrial ecosystem.

Relevant Information

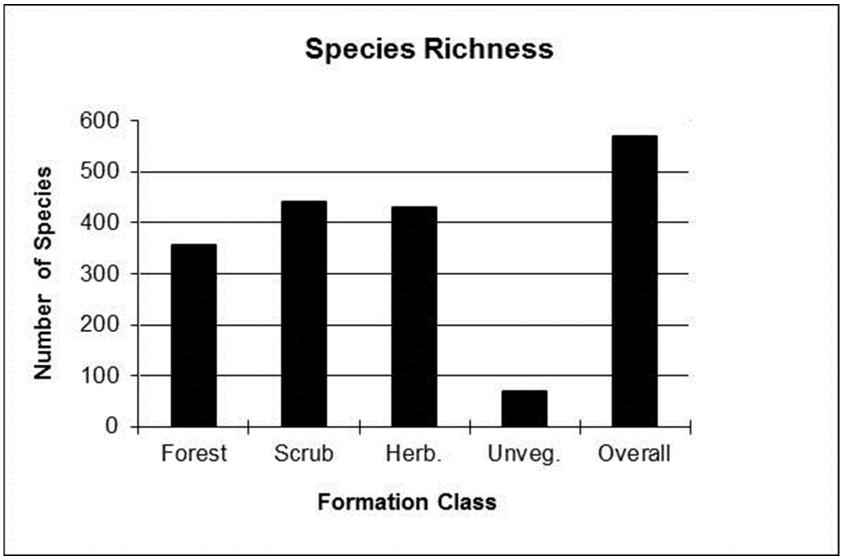
- Invasive plants have increased in number particularly in areas of human disturbance.
- The total area of infestation of highly invasive terrestrial plant species for the Chugach National Forest is estimated at less than 1,000 acres. About 86 percent of the non-native plant occurrences are located on the Kenai Peninsula. Focused treatments on less than 1,000 acres would limit the spread of highly invasive species known to occur within the Chugach National Forest.
- The spread of *Elodea* spp. (waterweed), a fish tank plant, is an emerging issue. It grows at lake margins and in sloughs on the Copper River Delta and in lakes on the Kenai National Wildlife Refuge. Recent Forest Service invasive species surveys reveal that the plant is spreading to new lakes and known populations are growing in size. This plant spreads very quickly, forming dense mats of floating and submerged leaves that can clog waterways and damage aquatic ecosystems.
- Initial modeling suggests that the Chugach National Forest will have variable ecological responses to climate change. The least change could occur in the coastal rainforests of Prince William Sound and the Copper River Delta, which are expected to remain as rainforests.
- The richness and diversity of the native vegetation within the Chugach National Forest likely provides a high level of resistance and resilience in response to climate change.

Terrestrial Ecosystems—Vegetation Key Ecosystem Characteristics

Vegetation diversity

The Chugach National Forest features a wide array of terrestrial plant communities. As described by DeVelice et al. (1999), the interaction of complex topography, varied climate, and periodic disturbance coupled with numerous plant species has resulted in a rich vegetation mosaic. The range of vascular plant (e.g., seed bearing plants and ferns) species richness (total number of species) across the national forest varies from less than 70 species in sparsely vegetated areas to more than 440 in shrublands (see figure 12 part A). More than 560 vascular plant species have been documented forestwide, equaling about one-third of the flora of Alaska. Additionally, more than 280 community types have been documented in the national forest (see figure 12 part B).

(A)*



(B)

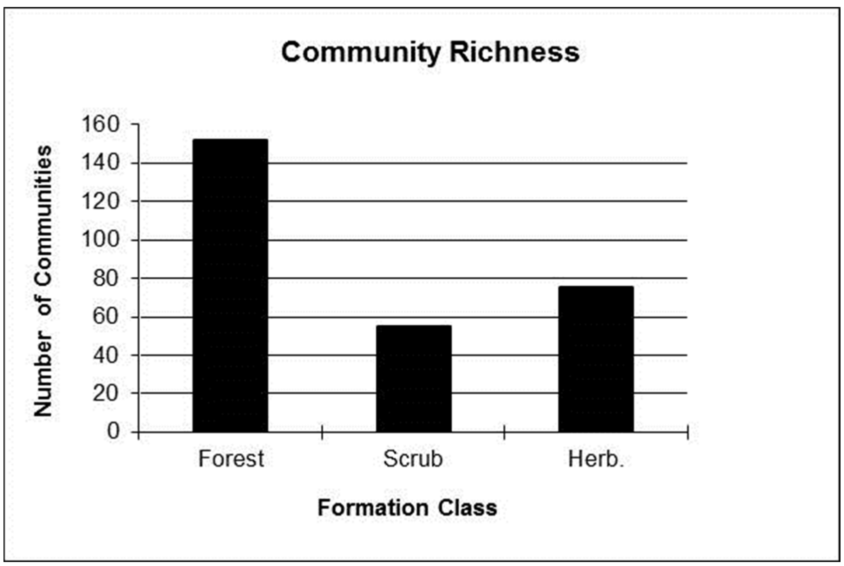


Figure 12. Vascular plant species richness (A) and plant community richness (B) by broad classes of forest, shrub, and herbaceous vegetation across the Chugach National Forest (DeVelice, et al., 1999)
*Unveg. indicates vegetation cover is less than 15 percent

DeVelice (2012a) evaluated existing land cover/vegetation maps for accuracy and utility for land management planning applications within the Chugach National Forest. The National Land Cover Database (NLCD) was found to be the best available classification spanning the national forest. Accuracy of NLCD in the Coastal Rainforest region of southcentral and southeast Alaska, including the area of the Chugach National Forest, was estimated at about 88 percent by Selkowitz and Stehman (2011).

The NLCD describes 19 land cover classes in Alaska. These land cover types are aggregated into one of five broad groupings: snow/ice/barren, shrubland, forested water, and herbaceous. Detailed descriptions of the 19 NLCD classes are in table 25. The approximate distribution of land cover across the Chugach National Forest is 43.0 percent snow/ice/barren, 30.0 percent shrubland, 22.7 percent forested, 2.7 percent water and 1.5 percent herbaceous. The approximate distribution of land cover across the Chugach National Forest and by geographic area in each of the five broad classes is displayed in the vegetation assessment map in the map package appendix and in table 26. The Kenai Peninsula, Prince William Sound, and Copper River Delta represent 20, 48, and 32 percent of the total acreage, respectively.

Table 25. NLCD class descriptions (Selkowitz & Stehman, 2011) for the 19 classes represented in Alaska*

Class ID	Aggregate	Description
12	Snow/ice/barren	**Perennial ice/snow:** All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
21	Snow/ice/barren	**Developed, open space:** Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	Snow/ice/barren	**Developed, low intensity:** Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20 to 49% of total cover. These areas most commonly include single-family housing units.
23	Snow/ice/barren	**Developed, medium intensity:** Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79% of the total cover. These areas most commonly include single-family housing units.
24	Snow/ice/barren	**Developed, high intensity:** Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100% of the total cover.
81	Snow/ice/barren	**Pasture/hay:** Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	Snow/ice/barren	**Cultivated crops:** Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
31	Snow/ice/barren	**Barren land (rock/sand/clay):** Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
51	Shrubland	**Dwarf scrub:** Alaska only areas dominated by shrubs less than 20 cm tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
52	Shrubland	**Shrub/scrub:** Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
90	Shrubland	**Woody wetlands:** Areas where forest or shrubland vegetation accounts for greater than 20% of vegetation cover and the soil or substrate is periodically saturated with or covered with water.

Class ID	Aggregate	Description
41	Forested	**Deciduous forest:** Areas dominated by trees generally greater than 5-m tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
42	Forested	**Evergreen forest:** Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	Forested	**Mixed forest:** Areas dominated by trees generally greater than 5-m tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
11	Water	**Open water:** All areas of open water, generally with less than 25% cover of vegetation or soil.
71	Herbaceous	**Grassland/herbaceous:** Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management, such as tilling, but can be utilized for grazing.
72	Herbaceous	**Sedge/herbaceous:** Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
95	Herbaceous	**Emergent herbaceous wetlands:** Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetation cover and the soil or substrate is periodically saturated with or covered with water.
74	Not applicable	**Moss:** Alaska only areas dominated by mosses, generally greater than 80% of total vegetation (note: not mapped within the boundary of the Chugach National Forest).

Table 26. Acreage by aggregated NLCD classes within the outer boundary of the Chugach National Forest, including lands of other ownership

Landcover Class	Acreage and Percent			Percent by Geographic Area		
	Hectares	Acres	Percent	Kenai Peninsula	Prince William Sound	Copper River Delta
Snow/Ice/Barren						
Perennial ice/snow	682,084	1,685,463	26.7	16.5	32.0	25.1
Developed	1,916	4,735	0.1	0.2	0.0	0.1
Barren land	416,267	1,028,616	16.3	16.6	12.6	21.6
Subtotals	*1,100,267*	*2,718,814*	*43.0*	*33.4*	*44.6*	*46.8*
Shrubland						
Dwarf shrub	71,872	177,598	2.8	14.1	0.0	0.0
Shrub/scrub	537,232	1,327,527	21.0	30.0	20.1	16.8
Woody wetlands	157,851	390,058	6.2	1.1	3.5	13.4
Subtotals	*766,955*	*1,895,184*	*30.0*	*45.2*	*23.6*	*30.2*
Forested						
Deciduous forest	33,546	82,893	1.3	1.4	0.8	2.0
Evergreen forest	541,957	1,339,204	21.2	15.9	28.9	13.0
Mixed forest	4,682	11,570	0.2	0.9	0.0	0.0
Subtotals	580,185	1,433,667	22.7	18.2	29.7	15.0
Water						
Open water	69,855	172,615	2.7	2.6	1.8	4.2
Herbaceous						
Herbaceous	7,121	17,597	0.3	0.1	0.3	0.4
Emergent herbaceous wetlands	31,411	77,617	1.2	0.5	0.1	3.4
Subtotals	*38,532*	*95,214*	*1.5*	*0.6*	*0.4*	*3.8*
Totals	**2,555,794**	**6,315,494**	**100**	**100**	**100**	**100**

Vegetation by geographic area

The 2002 Forest Plan FEIS summarized ecological diversity based primarily on land cover/vegetation types, vegetation structure, and a bioenvironmental classification comprised of generalized climate, land cover, and landform. The Kenai Peninsula, the Prince William Sound, and the Copper River Delta were considered (see figure 13). Some characteristic plants of these areas by broad land cover class are summarized here. DeVelice et al. (1999) and Boggs (2000) provide detailed descriptions of the vegetation composition and structure across the Chugach National Forest.

Snow, ice, and barren

Predominant plants within the mostly non-vegetated rock and ice dominated upper elevations of the Chugach and Saint Elias mountains are lichens and dwarf shrubs (e.g., crowberry, Steller's cassiope, luetkea, and bog blueberry).

Forested

The greatest percentage of forested cover occurs on Prince William Sound at about 30 percent (see table 26 and the vegetation assessment map in the map package appendix). Forests of Prince William Sound and the Copper River Delta are temperate rainforests while the Kenai Peninsula forests are transitional between boreal forests and temperate rainforests. Characteristic evergreen trees are Lutz spruce (hybrid between white and Sitka spruces) and occasional black spruce on the Kenai Peninsula, mountain hemlock on the Kenai Peninsula and Prince William Sound, and Sitka spruce and western hemlock in the Prince William Sound and Copper River Delta. Prince William Sound is the home to the northwestern range limits of western hemlock and yellow-cedar. The mountain hemlock of the Kenai Peninsula and Prince William Sound occurs primarily on side slopes at low to mid elevations while the spruces of the Chugach National Forest may dominate on both valley bottoms and side slopes. On the Copper River Delta, the forests frequently occur as strings of trees (especially on slough levees) between adjacent open wetlands.

Kenai paper birch is a dominant deciduous tree species and a major component of the mixed forests of the Kenai Peninsula, and quaking aspen forests occur sporadically on southern side slopes. Black cottonwood is commonly found in the valley bottoms of the Kenai Peninsula and on the Copper River Delta. Deciduous forests are least common in Prince William Sound with occasional occurrences of black cottonwood.

Early blueberry and devil's club are common undergrowth species of the forests of the Chugach National Forest. Bluejoint reedgrass, lowbush cranberry, crowberry, and Schreber's feathermoss are especially common on the Kenai Peninsula. Rusty menziesia, wood fern, and splendid feathermoss are common both on the Kenai Peninsula and in Prince William Sound. Copperbush, deer cabbage, Pacific reedgrass, and gooseneck mosses are common in Prince William Sound. Salmonberry and skunk cabbage are common on both Prince William Sound and the Copper River Delta. The black cottonwood forests of the Copper River Delta often have an undergrowth of Sitka alder and willow.

Shrubland and herbaceous vegetation

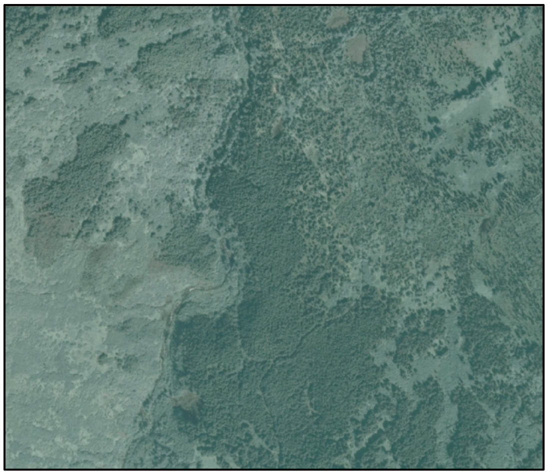
The Kenai Peninsula has the greatest percentage of shrubland cover at about 45 percent, and the Copper River Delta has the greatest percentage of herbaceous cover at about 4 percent (see table 26 and figure 13). Sitka alder is a characteristic shrubland species of all three geographic areas.

On the Kenai Peninsula, the non-forested slopes below the alpine zone are often characterized by alternating stringers of tall shrubs dominated by Sitka alder and rich herbaceous communities with such species as tall fireweed, bluejoint reedgrass, northern geranium, and lady fern. In Prince William Sound, tall shrubland dominated by Sitka alder and salmonberry characterize avalanche chutes and beach fringe areas. Characteristic dominants of the Copper River Delta shrublands include sweetgale, Sitka alder, Barclay willow, and Sitka willow.

Characteristic species of the low shrubland and herbaceous communities of both the Kenai Peninsula and Prince William Sound include crowberry, Steller's cassiope, bog blueberry, luetkea, and bluejoint reedgrass. In addition, white mountain-avens and rough fescue are common on the Kenai Peninsula and Aleutian mountain heath, tall cotton grass, tufted bulrush, beach rye, Lyngbye's sedge, fewflower sedge, manyflower sedge, and sphagnum mosses are common on Prince William Sound.

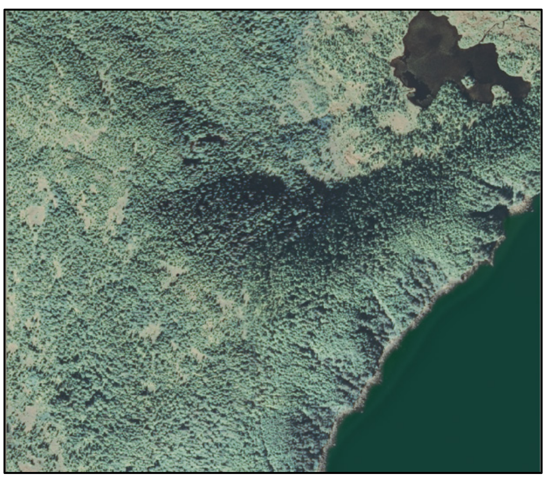
Dominant wetland herbaceous communities of the Copper River Delta include swamp horsetail, marsh fivefinger, buckbean, Lyngbye's sedge, Sitka sedge, burreed, yellow pondlily, dwarf alkaligrass, Pacific silverweed, Nootka lupine, tall fireweed, and beach rye.

Lynx Creek, Kenai Peninsula



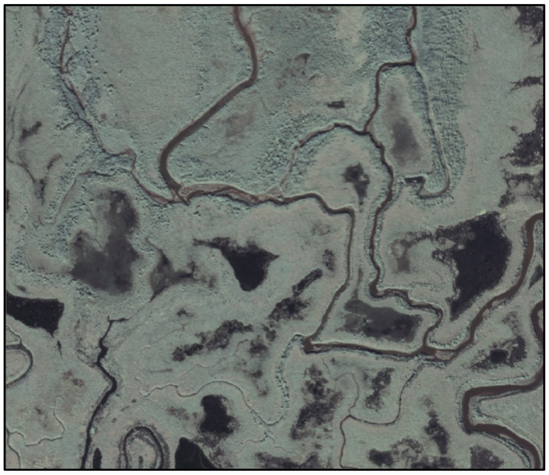
Forests
mountain hemlock, Lutz spruce, mountain hemlock-Lutz spruce, paper birch, black cottonwood, Lutz spruce-paper birch, and Lutz spruce-black cottonwood
Shrublands
willows and Sitka alder
Herbaceous
mesic graminoid and mesic forb

Peak Island, Prince William Sound



Forests
western hemlock, western hemlock-Sitka spruce, mountain hemlock, and mountain hemlock-western hemlock
Shrublands
ericaceous shrub bog

Copper River Delta south of the Sheridan River



<u>Shrublands</u>
Sitka alder, Sitka alder-willow, and sweetgale
<u>Herbaceous</u>
mesic graminoid, wet graminoid, mesic forb, wet forb, and freshwater aquatic herbaceous

Figure 13. Examples of vegetation patterns in the Kenai Peninsula, Prince William Sound, and Copper River Delta geographic areas. The dimension of each is about 0.73 mile (width) by 0.63 mile (height).

Vegetation pattern across the landscape

Fragstats 4.1 (McGarigal & Marks, 1995; McGarigal, Cushman, & Ene, 2012) was used to summarize the spatial pattern of vegetation (as mapped by NLCD) across the Chugach National Forest. Analyses were done forestwide and for the three geographic areas. A selection of nine metrics was used in the analysis. Summaries of the highlights of the estimates for these metrics follow.

Total area

This is a measure of landscape composition, specifically, how much of the landscape is comprised of a particular patch type.

Perennial ice/snow is the most abundant class forestwide covering more than 1,680,300 acres (680,000 hectares) Perennial ice/snow is also the most abundant class on Prince William Sound and on the Copper River Delta (more than 963,700 and 494,200 acres (390,000 and 200,000 hectares), respectively). On the Kenai Peninsula, shrub/scrub is most abundant at more than 370,700 acres (150,000 hectares).

Percentage of landscape

Like total area, this is a measure of landscape composition. However, percentage of landscape is a relative measure and is useful for comparing landscapes of varying sizes.

Forestwide, the perennial ice/snow, evergreen forest, and shrub/scrub classes individually exceed 20 percent of the landscape (and total 69 percent). Perennial ice/snow, evergreen forest, and shrub/scrub classes also individually exceed 20 percent of the Prince William Sound landscape (and total 81 percent). Perennial ice/snow and barren land are the only classes individually exceeding 20 percent of the Copper River Delta landscape (and total about 47 percent). On the Kenai Peninsula, the only class exceeding 20 percent of the landscape is shrub/scrub (30 percent).

The combined acreage in the developed classes (i.e., NLCD classes 21, 22, 23, 24, 81, and 82 of table 25) total about 0.1 percent of the forestwide landscape (about 0.2 percent of the Kenai Peninsula). This suggests that about 99.9 percent of the landcover pattern across the Chugach National Forest is primarily reflective of non-intensive management/development. As such, the summary results presented here may be regarded as representing natural process generated landcover conditions.

Patch density

This measure expresses the number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size.

The shrub/scrub class has the highest patch density forestwide and in each of the three geographic areas, exceeding 1.5 patches/247.5 acres (100 hectares) in all cases. The only other class exceeding 1.5 patches/247.5 acres threshold is open water in Prince William Sound.

Largest patch index

This measure quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

Perennial ice/snow form the largest patch forestwide and within the Prince William Sound and Copper River Delta geographic areas (about 8, 16, and 8 percent of each area, respectively). On the Kenai Peninsula, the largest patch is shrub/scrub (about 14 percent).

Edge density

This measure reports edge length on a per unit area basis that facilitates comparison among landscapes of varying size.

Shrub/scrub vegetation has the highest edge density forestwide and on each of three geographic areas (exceeding 131 feet/2.5 acres (40 meters/hectare) in all cases). Edge density also exceeds 131 feet/2.5 acres (40 meters/hectare) in evergreen forests forestwide (about 144 feet/2.5 acres (44 meters/hectare)) and in Prince William Sound (about 183 feet/2.5 acres (56 meters/hectare)).

Landscape shape index

This index provides a standardized measure of total edge or edge density that adjusts for the size of the landscape.

As with edge density, shrub/scrub vegetation has the highest landscape shape index forestwide and for each of three geographic areas. This is followed by evergreen forests both forestwide and in Prince William Sound.

Perimeter-area fractal dimension

This measure reflects shape complexity across a range of spatial scales (patch sizes). It approaches one for shapes with very simple perimeters, such as squares, and approaches two for shapes with highly convoluted perimeters.

The two classes representing greater than 10 percent of each respective landscape forestwide and the three geographic areas with the largest difference in perimeter-area fractal dimension are perennial ice/snow (lower fractal dimension, simpler perimeter) and shrub/scrub (higher fractal dimension, more convoluted perimeter). The forestwide values are 1.42 and 1.64. Values are 1.39 and 1.61 for the Kenai Peninsula; 1.44 and 1.64 for Prince William Sound; and 1.41 and 1.65 for the Copper River Delta.

Patch cohesion

This index measures the physical connectedness of the corresponding patch type. The index approaches zero as the proportion of the landscape comprised of the class of interest decreases and becomes increasingly subdivided and less physically connected. The index increases as the proportion of the landscape comprised of the focal class increases.

The patch cohesion index varies from about 60 to 100 percent across the Chugach National Forest. The index exceeds 90 percent for 11 of 18 classes forestwide, 10 of 18 classes on the Kenai Peninsula, 6 of 15 classes in Prince William Sound, and 9 of 15 classes on the Copper River Delta. This suggests that most landcover classes are highly connected within the Chugach National Forest, but this is less so in Prince William Sound (with abundant islands, and thus a more subdivided landscape).

Normalized landscape shape index

This is the normalized version of the landscape shape index (LSI) and provides a measure of class aggregation or clumpiness. The normalization essentially rescales LSI to the minimum and maximum values possible for any class area. The index equals zero when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type. The index increases as the patch type becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated (i.e., a checkerboard).

Forestwide, the normalized landscape shape index varies from 0.05 (highly aggregated) for the perennial snow/ice class to 0.62 (moderately disaggregated) for the sedge/herbaceous class. Similarly, on the Kenai Peninsula, the index varies from 0.06 for the perennial snow/ice class to 0.63 for the sedge/herbaceous class. In Prince William Sound and on the Copper River Delta, the index varies from 0.04 and 0.06 for the perennial snow/ice class to 0.63 and 0.67 for the mixed forest class, respectively.

Terrestrial Ecosystems—Vegetation Drivers and Stressors

Composition and production of an ecosystem is a function of species interactions and biotic responses to environmental drivers. The primary environmental regimes affecting organisms include moisture, temperature, radiation, nutrients, and biotic (Nix, 1982). These regimes are a function of the interaction of climate, topography, soils, and vegetation. Disturbances, both natural and human-caused, further modify ecosystem composition, structure, and succession.

One item of particular note in regard to nutrient regimes in the Chugach National Forest is the role of salmon. Salmon transport marine-derived nitrogen to the streams in which they reproduce. Trees and shrubs near spawning streams have been found to derive about 23 percent of their nitrogen from salmon (Helfield & Naiman, 2001). As a result of this nutrient subsidy, growth rates in plants have been found to be significantly increased near spawning streams. This may act as a positive feedback mechanism by which salmon borne nutrients improve spawning and rearing habitat for subsequent salmon generations and maintain the long-term productivity of river corridors (Helfield & Naiman, 2001).

Natural Disturbance Regimes

Ecological patterns across the national forest are primarily the result of natural processes. Natural disturbances within the national forest include natural fire ignited by lightning, native insect and disease outbreaks, earthquakes, volcanic ash fall, snow avalanches, landslides, windthrow, glacial action, floods, and beaver activity.

Natural fire

Owing to the generally cool, moist climate and low incidence of lightning, natural fires are infrequent within the Chugach National Forest. When fire does occur, it is usually during drought or dry periods resulting in intense fires. This generally results in stand replacement since most plant species present are not adapted to survive fire. As noted in the 2002 Forest Plan FEIS, fire has been an important disturbance process on the Kenai Peninsula geographic area (USDA, 2002c). Radiocarbon dates of charcoal layer samples from soils at scattered locations in the Kenai Mountains ranged from 3,010 to 570 years before present. This indicated a long time between fire intervals (average of 600 years) (Potkin, 1997).

Biophysical settings are environmental descriptors used for determining a landscape's natural fire regimes and vegetation characteristics (Barrett, et al., 2010). According to Fire Regime Condition Class, the following 10 biophysical settings are represented within the Chugach National Forest (along with the estimated mean fire return interval and characteristic fire severity) (NWCG, 2014):

- Black spruce southcentral: 80 to 200 year interval; 90 percent overstory replacement
- Coastal boreal transition forest: 600 to 800 year interval; 90 percent overstory replacement
- Coastal forests: 600 to 3,000 year interval; 90 percent overstory replacement
- Kenai Mountains hemlock: 600 to 3,000 year interval; 80 percent overstory replacement
- Riparian spruce hardwood-Kenai: 650 year mean interval; 10 percent overstory replacement
- Dwarf scrub tundra: 500 to 1,000 year interval; 90 percent replacement
- Persistent shrub south: 900 year mean interval; 70 percent replacement
- Dry herbaceous meadow: 170 year mean interval; 85 percent replacement
- Mesic herbaceous meadow: 350 year mean interval; 70 percent replacement
- Non-forested wetland: 1,000 year mean interval; 60 percent replacement

Native insect and disease outbreaks

A spruce bark beetle (*Dendroctonus rufipennis*) infestation killed the majority of mature spruce trees across at least 40,000 acres (16,000 hectares) of the Kenai Peninsula geographic area. The infestation began in the 1950s and peaked in the 1990s (USDA, 2012b). Based on tree core evidence, Berg et al. (2006) found that a spruce bark beetle infestation occurred on the Kenai Peninsula in the late nineteenth century, similar to the recent outbreak in magnitude and size. Since much of the mature spruce on the Kenai Peninsula has already been killed by spruce bark beetles, few acres of further infestation are expected in coming decades. The 2011 R10 Forest Health Protection Report (Mulvey & Lamb, 2012) states that spruce bark beetle activity had declined to the lowest level in 35 years.

Results of annual monitoring of insect and disease activity in Alaska forests are provided in reports by the Forest Health Protection unit of State and Private Forestry. Based on these reports, the area affected by insects and diseases varies from year to year across Alaska. From 2002 through 2012, 22 different diseases and insect pests damaged approximately 523,000 acres in southcentral Alaska, including the Chugach National Forest (see table 27) (Lundquist, Winton, Wurtz, & Heutte, 2013). The number of acres affected varied from about 107,000 acres in 2004 to about 2,000 acres in 2008. Phloem feeders (primarily spruce bark beetles) accounted for 18 percent of the affected landscape, diseases occurred on 15 percent, hardwood defoliators affected 62 percent, and conifer defoliators affected 5 percent.

Insects and disease disturbance to vegetation can generate early seral habitat and alter habitat diversity, such as edge habitat and microhabitats important to many wildlife species. In addition, single tree mortality caused by heart rot fungi is important in creating canopy gaps (Hennon, 1995).

Table 27. Acres of forest damage mapped by aerial surveys in the broader southcentral Alaska landscape that includes the Chugach National Forest (Lundquist, Winton, Wurtz, & Heutte, 2013)

Agent	**Acres of Forest Damage Mapped by Aerial Survey by Year**											
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Totals All Years**
Spruce bark beetle	10,560	18,399	6,443	8,102	13,565	18,636		8,401	3,652	5,873	1,245	94,876
Ips engraver beetle	32			187	107	82						408
Total spruce mortality	**10,592**	**18,399**	**6,443**	**8,289**	**13,672**	**18,718**	**0**	**8,401**	**3,652**	**5,873**	**1,245**	**95,284**
Alder dieback			5,692						17,038	55,780	26	78,536
Spruce broom rust					11					4		15
Spruce needle rust									14	24		38
Total disease	**0**	**0**	**5,692**	**0**	**11**	**0**	**0**	**0**	**17,052**	**55,808**	**26**	**78,589**
Alder defoliation	0		163	1,840	1,883			223		24,210	13,569	41,888
Alder leaf roller	623	1,616	27	0	113							2,379
Aspen defoliation				77						14		91
Aspen Leaf Miner	0	9	21		1,385	593		4,213	3,330	17		9,568
Betula nana defoliation										3,952		3,952
Birch defoliation	0		127	396	368				1,409	13,678	4,406	20,384
Birch Leaf Miner	29,692	31,902	93,240	28,477								183,311
Birch leaf roller	46	1,613	107	5,648	276							7,690
Cottonwood defoliation	235	11,228		1,051		91		659	221	8,530	384	22,399
Cottonwood Leafroller	46	71	147		4,342							4,606
Hardwood defoliation		14		864						3,324	2,210	6,412
Large aspen tortrix			404		1,639	170			136	116		2,465
Spear-marked black moth								14,309	157			14,466
Willow defoliation	1	55		11	1,492	44	3		916	514	443	3,479
Total hardwood defoliation	**30,643.0**	**46,508**	**94,236**	**38,364**	**11,498**	**898**	**3**	**19,404**	**6,169**	**54,355**	**21,012**	**323,090**

Agent	Acres of Forest Damage Mapped by Aerial Survey by Year											
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Totals All Years**
Black-headed budworm	3,004	1,267	105	1,401	522	6,810	1,994	647				15,750
Conifer defoliation			229	2,183						1,629		4,041
Spruce needle aphid		48		5,054		648						5,750
Total conifer defoliation	**3,004**	**1,315**	**334**	**8,638**	**522**	**7,458**	**1,994**	**647**	**0**	**1,629**	**0**	**25,541**
Total all agents	**44,239**	**66,222**	**106,705**	**55,291**	**25,703**	**27,074**	**1,997**	**28,452**	**26,873**	**117,665**	**22,283**	**522,504**

Earthquakes

As a result of the Great Alaska Earthquake in 1964, which uplifted the Copper River Delta between 6 and 11 feet, some low elevation vegetation changed from a system dominated primarily by graminoids and forbs to a mosaic of forb-graminoid wetlands with patches of woody vegetation (DeVelice, Boudreau, Wertheim, Hubbard, & Czarnecki, 2001). Mudflats that were subtidal prior to the earthquake are becoming tidal marsh, and woody plants are becoming more dominant on the uplifted tidal marsh. These changes to wetland communities are important to many waterfowl on the Copper River Delta, particularly the dusky Canada goose. Vegetation changes also resulted in saltwater inundated areas due to the tsunami waves associated with the earthquake.

Earthquakes of the magnitude of the Great Alaska Earthquake occur at a frequency of perhaps once every 300 to 800 years in southcentral Alaska. However, earthquakes of lesser magnitude but capable of causing landslides and other environmental disturbances occur at a much higher frequency.

Volcanic ash fall

Volcanic activity is common in the coastal mountains west of the Chugach National Forest. Ash fall from this activity sometimes travels to the national forest and accumulates on the vegetation, which can cause stem breakage, inhibit transpiration and photosynthesis, and alter growth. In some cases, the ash can cause an increase in production due to mulching and fertilizing effects.

Snow avalanches

The vegetation pattern on many mountain slopes of the Chugach National Forest is shaped by snow avalanches (DeVelice personal observation; see figure 14). Many locations otherwise capable of supporting forest vegetation are maintained in shrubland and herbaceous states by periodic snow avalanches. Avalanches are a common cause of death of Dall’s sheep and mountain goats.

In addition to contributing to avalanches, snow and ice accumulations on stems and branches can cause breakage resulting in fine scale alterations to vegetation composition and structure.

Figure 14. View of vegetation pattern on mountain slopes above Summit Lake on the Kenai Peninsula. The predominance of shrubland and herbaceous vegetation is largely maintained by periodic snow avalanches. The mountain hemlock forests at left are on a slope where avalanches are rare. This pattern is widespread within the Chugach National Forest.

Landslides

Landslides are not a common occurrence in the Chugach National Forest. They occur most frequently on steep slopes with soils that have a layer restrictive to downward water flow, usually bedrock or compact till. Natural landslides have been noted in Prince William Sound and scattered across the Kenai Peninsula. Landslides associated with past logging activity have been noted on Montague Island and in the Knowles Head area in Prince William Sound. Localized landslides can be important to wildlife diversity by creating small scale patches of early seral vegetation.

Windthrow

Windthrow is important in forest succession within the Chugach National Forest but has not been rigorously documented. In the forests of southeast Alaska, which are similar to at least some of the forests of the Chugach National Forest, Nowacki and Kramer (1998) and Kramer et al. (2001) found a continuum of wind disturbance intensity grading from small-scale canopy gaps predominating in wind-protected areas to stand replacement in areas exposed to large-scale wind events. The pattern of windthrow in southeast Alaska was found to be predictable based on exposure to prevailing storm winds, slope, elevation, soil stability, and landform (Kramer, Hansen, & Taper, 2001). In addition, windthrow and tree breakage caused by wind can strongly increase spruce bark beetle and wood borer activity (Burnside, et al., 2011; Gardiner, 1975; Holsten, Their, Munson, & Gibson, 1999) and permit entry of stain and decay fungi.

Glacial action

Within the Chugach National Forest, 43 percent of the landcover classified as snow, ice, or barren is covered by glaciers. Some glaciers are retreating while others are advancing. Glacial action can have a profound effect on the landscape by abrading rock and debris with their advance, leaving behind initially unvegetated terrain as they melt.

Floods

Stream flows within the Chugach National Forest are primarily influenced by natural processes since the majority of the national forest is undeveloped (USDA, 2012b)). Stream flows are primarily dependent on runoff from snowmelt, rainfall, and glacial melt and vary by watershed size, climate, and the presence of glaciers. Processes causing changes in stream flows include glacial melting, temperature and precipitation fluctuations, geomorphic channel changes, and glacial outburst floods. Flooding is an important hydrologic and ecological function that maintains healthy hyporheic zones (subsurface volume of sediment and porous space adjacent to a stream through which water readily exchanges) and aquatic diversity.

Beaver activity

Beavers have a profound effect on the landcover composition of some areas of the Copper River Delta (DeVelice, DeLapp, & Wei, 2001a).

Non-natural disturbances and stressors

Most of the human activity on the Chugach National Forest occurs along railroads; powerlines; developed and decommissioned roads and trails; and areas open to snowmachines, skiing, heli-skiing, and OHVs. Additional human disturbances occur around water developments, rivers used by boaters and anglers, beaches and boat launches, and small developments, such as electronic transmission sites, cabins, airplane landing strips, dispersed campsites, signs, and fences. Human activity and use varies greatly by season, extent, and duration. Because many of these activities do not require permits from the Forest Service, it is difficult to estimate the amount or extent of use.

Soil disturbance

The 2002 Forest Plan FEIS noted five major activities that expose mineral soil and reduce soil productivity. These are road construction, vegetation treatment, placer mining, recreational development, and trampling vegetation, which exposed soils adjacent to streams. Landslides have occurred in some areas where roads have cut a portion of the retaining slope, in areas where vegetation treatment has occurred on steep slopes with shallow soil over bedrock, and in areas of road construction on unstable soils on steep slopes with saturated soil.

Human-caused fire

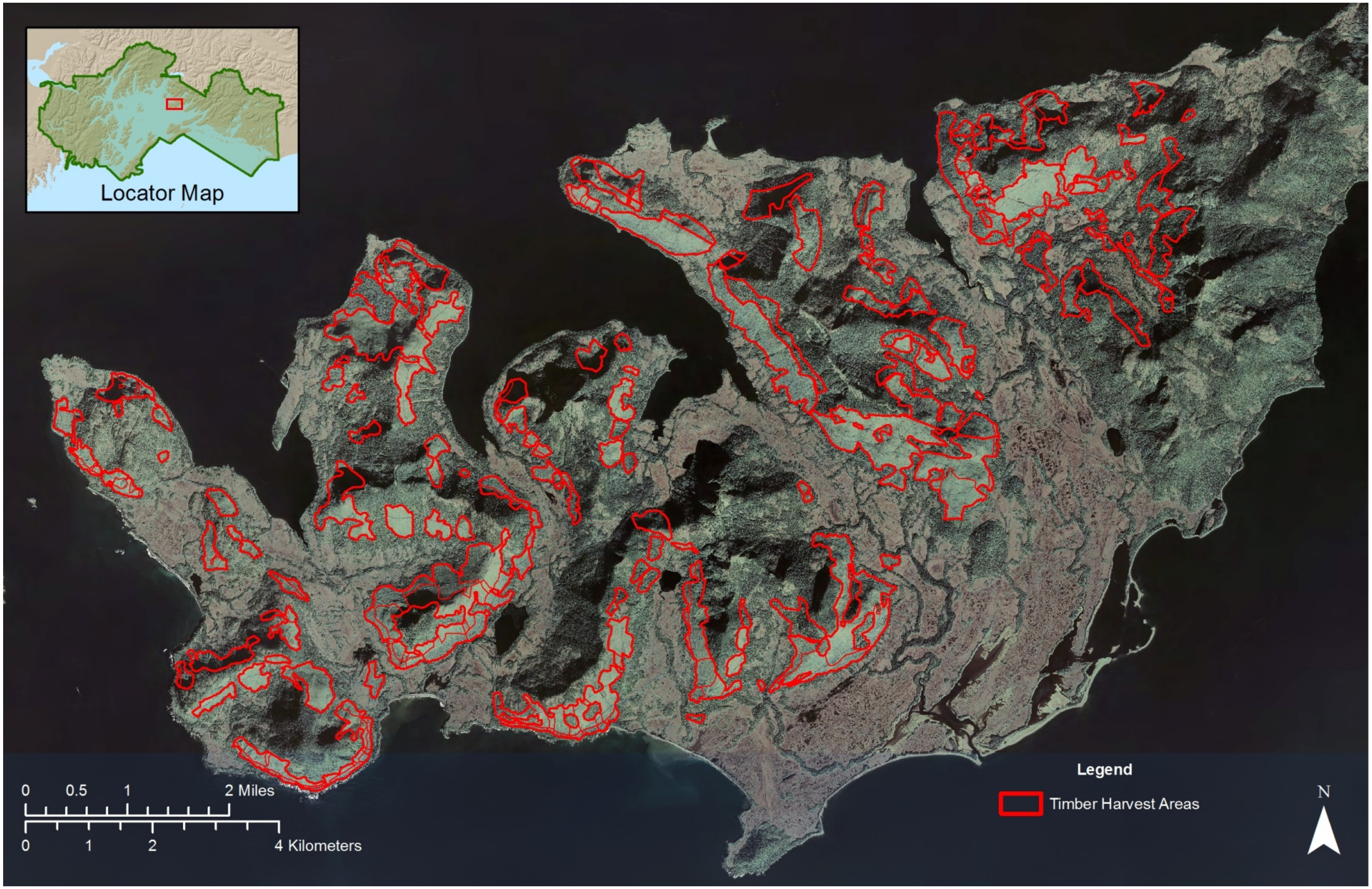
The present forest vegetation pattern on the Kenai Peninsula geographic area reflects human-caused fires that occurred during the last 100 years or so, creating areas of early successional plant communities, including large stands of broadleaved forests. About 1,400 fires burned a combined 75,000 acres (30,350 hectares) on the Kenai Peninsula geographic area from 1914 to 1997 (Potkin, 1997). Human-caused ignitions account for more than 99 percent of these fires (see the Fire Management section). Alaska Natives have been present in southcentral Alaska for thousands of years, but there is no evidence that they used fire as a land management tool (Berg, personal communication, 2013).

Vegetation treatments

The largest amount of ongoing vegetation treatment within the Chugach National Forest is hazardous fuel reduction on the Kenai Peninsula, where an average of about 875 acres is treated annually (a range of about 400 to 1,500 acres from 2004 through 2013). Treatments consist of removal, thinning, pruning, piling, and burning especially in the wildland/urban interface, high use areas, and transportation routes.

Wildlife habitat improvement, forest vegetation establishment and improvement, and invasive plant treatment projects also occur within the national forest. Based on data in the Forest Service Activity Tracking System (FACTS) and on file, annual forest vegetation establishment and improvement acreage ranged from about 200 to 680 acres and annual invasive plant control from 25 to 120 acres from 2004 through 2013.

Very little timber harvest occurs within the Chugach National Forest. Most of the recent logging occurred in the 1990s on private lands within the national forest matrix. Some of those logged lands are now National Forest System lands, i.e., much of the Knowles Head Peninsula in Prince William Sound (see map 5).



Map 5. Timber harvest on the Knowles Head Peninsula, Prince William Sound. The areas delineated in red total about 7,340 acres (2,970 ha)

Invasive species

A species is considered to be invasive if it meets two criteria: (1) it is non-native to the ecosystem under consideration, and (2) its introduction causes, or is likely to cause, economic or environmental harm or harm to human health (Executive Order 13112). Invasive species can endanger native species and threaten ecosystem services and resources, including clean water, recreational opportunities, sustained production of wood products, fish and wildlife habitat, and human health and safety (USDA, 2013). Adverse effects from invasive species can be exacerbated by interactions with fire, native pests, weather events, human actions, and environmental change. (Pimentel, et al., 2001) estimated damage from invasive species worldwide totals more than 1.4 trillion dollars per year (about 5 percent of the global economy).

Invasive plants

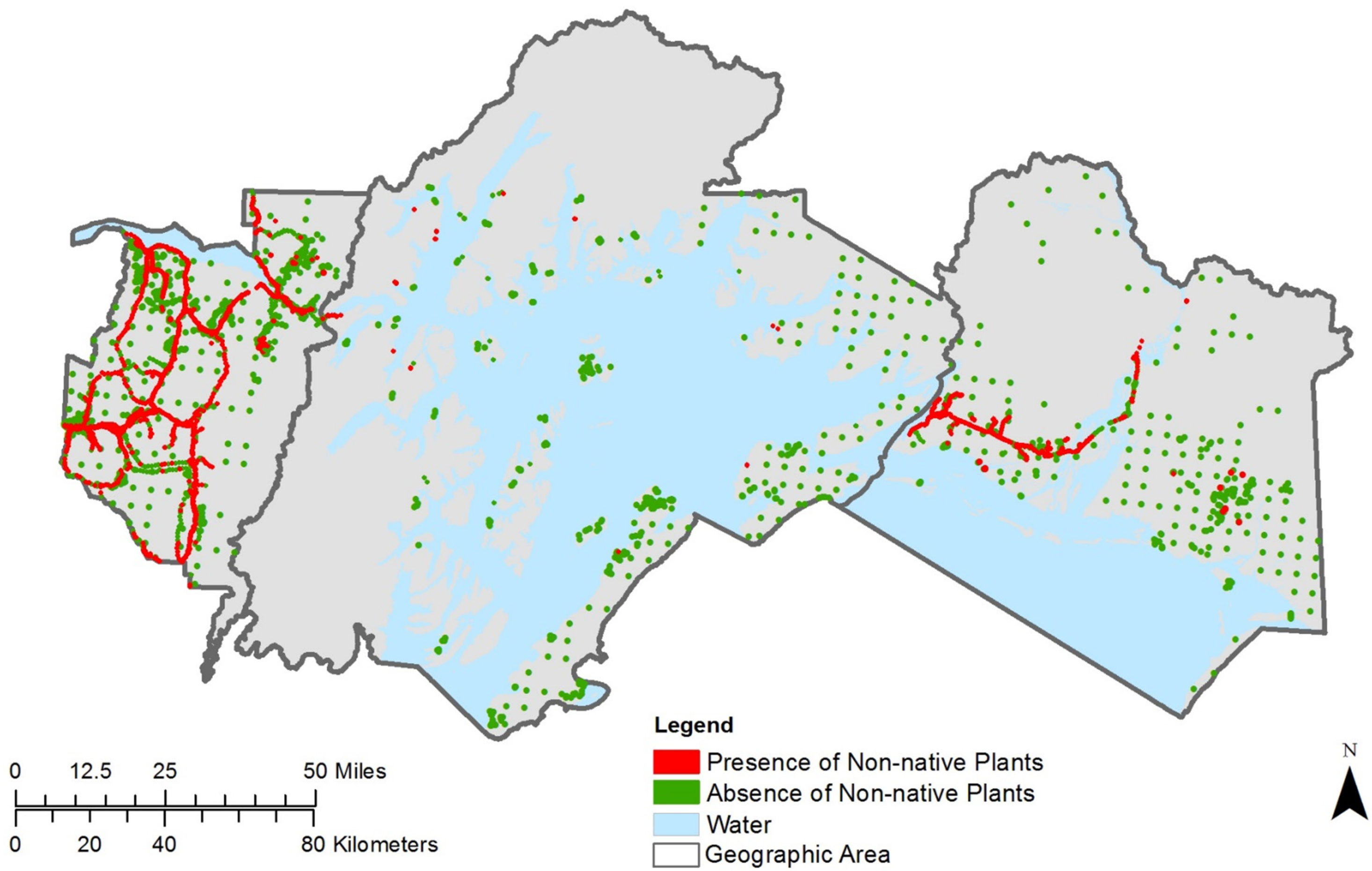
Most non-native plant occurrences within the national forest are in areas of intensive human-caused disturbance. Non-native plants have been found on about 71 percent of the sites sampled on road edges, facilities, trailheads, mineral material sites, trails, and shorelines of the Chugach National Forest (based on NRIS TESP-Invasive Species data; see table 28). In contrast, about one percent of backcountry sites sampled have non-native plants present (based on Chugach National Forest ecology plot and FIA data; see table 28). About 86 percent of occurrences of non-native plants within the national forest are on the Kenai Peninsula (based on combined NRIS TESP-Invasive Species data, Chugach National Forest Ecology plot data, and FIA data; see table 28 and map 6).

Non-native plants within the Chugach National Forest have been given an invasiveness rank on a scale of zero to 100. Species ranked 70 or greater on this scale are considered to be highly invasive. Of the 92 non-native plant species currently documented within the boundary of the Chugach National Forest, 11 are considered highly invasive (see table 29). None of these highly invasive species have been found in the backcountry (Carlson, et al., 2008). Of the 5.4 million acres of National Forest System lands, the total area of infestation of highly invasive plants is estimated at less than 1,000 acres (400 hectares) (DeVelice, Nawrocki, Charnon, & Mohatt, 2012).

Table 28. Summary of non-native plant species occurrences within the boundary of the Chugach National Forest based on data in NRIS TESP-Invasive Species, Forest Inventory and Analysis (FIA), and the Chugach National Forest Ecology Program vegetation plot databases

Data Variable	**Geographic Area**			**National Forest Totals**
	Kenai Peninsula	**Prince William Sound**	**Copper River Delta**	
All Data				
Occurrence records	9,362	70	1,424	10,856
Non-occurrence records	1,748	705	835	3,288
Sum	11,110	775	2,259	14,144
Percent of forestwide occurrences	86.2%	0.6%	13.1%	100%
Front Country Records				
Occurrence records	9,355	70	1,403	10,828
Non-occurrence records	481	25	155	661
Sum	9,836	95	1,558	11,489
Percent of sum	95.1%	73.7%	90.1%	94.2%
Front Country Sites				
Occurrence sites	1,260	25	309	1,594
Non-occurrence sites	481	25	155	661
Sum	1,741	50	464	2,255
Percent of sum	72.4%	50.0%	66.6%	70.7%
Backcountry Sites				
Occurrence sites	7	0	20	27
Non-occurrence sites	1,267	680	680	2,627
Sum	1,274	680	700	2,654
Percent of sum	0.5%	0.0%	2.9%	1.0%
Number of Species				
Non-native species	84	22	43	92
Highly invasive species	8	5*	6	11

*All five occurrences of highly invasive species in Prince William Sound are in the Whittier area.



Map 6. Non-native plant species occurrence (red dots) and non-occurrence (green dots) records currently documented on the Chugach National Forest. The Kenai Peninsula, Prince William Sound, and Copper River Delta geographic areas are also displayed (left to right, respectively).

Table 29. Non-native plant species currently documented within the Chugach National Forest with invasiveness ranks ≥ 70 (highly invasive) (AKNHP, 2013).

Scientific Name	Common Name	Rank	Quantity*	Area
Cirsium arvense	Canada thistle	76	6	Girdwood
Elodea spp.	Waterweed	79	21	Copper River Delta
Hieracium aurantiacum	Orange hawkweed	79	16	Kenai Peninsula and Cordova
Lupinus polyphyllus	Bigleaf lupine	71	36	Kenai Peninsula, Whittier, and Copper River Delta**
Melilotus alba	White sweetclover	81	32	Kenai Peninsula, Whittier, and Cordova
Phalaris arundinacea	Reed canarygrass	83	31	Kenai Peninsula, Whittier, and Copper River Delta
Polygonum x bohemicum	Bohemian knotweed	87	0	Cordova (not yet entered in NRIS)
Prunus padus	European bird cherry	74	1	Kenai Peninsula (near Hope)
Rosa rugosa	Rugosa rose	72	1	Whittier
Sochus arvensis	Perennial sowthistle	73	1	Kenai Peninsula (Hope Wye); eradicated from site
Vicia cracca	Bird vetch	73	35	Kenai Peninsula and Whittier

*Number of populations reported in NRIS TESP-Invasive Species out of 10,828 non-native plant species occurrence records within the boundary of the Chugach National Forest.
**Bigleaf lupine may be native in some locations within the Chugach National Forest.

Because invasive plants have relatively limited distributions within the Chugach National Forest, managers are in a unique position to prevent the introduction and spread of invasive plants and to eradicate small populations before they spread. However, effects of changing climate, increasing levels of disturbance (both natural and human-caused), and increasing tourism and population growth make the national forest vulnerable to the introduction and spread of invasive plants.

The spread of *Elodea* spp. (waterweed), a fish tank plant, is an emerging issue. It grows at lake margins and in sloughs on the Copper River Delta and in lakes on the Kenai National Wildlife Refuge (populations are also known from Fairbanks and Anchorage). Recent Forest Service invasive species surveys reveal that the plant is spreading to new lakes and known populations are growing in size. This plant spreads very quickly, forming dense mats of floating and submerged leaves that can clog waterways and damage aquatic ecosystems. Agencies and communities are in early stages of cooperating to respond to the problem of *Elodea*.

Invasive insects and pathogens

The most invasive non-native insect within the Chugach National Forest is the amber-marked birch leaf miner (*Profenusa thomsoni*). It was first discovered in Anchorage in 1996 and has spread across the Matanuska-Susitna Valley. Infestations have also been documented in Fairbanks, Haines, Skagway, and a large part of the Kenai Peninsula (Holsten, Hennon, Trummer, Kruse, Schultz, & Lundquist, 2009). Occurrences are very much localized within the Chugach National Forest (Alaska Wildland Fire Coordinating Group, 2010) (Ludquist, personal communication, 2013). Since monitoring began in 2006, amber-marked birch leaf miner activity has been decreasing in the Anchorage area (Lundquist, Reich, & Tuffly, 2012; Mulvey & Lamb, 2012).

The green alder sawfly (*Monsoma pulveratum*) has been found actively defoliating thin-leaf alder (*Alnus tenuifolia*) in Anchorage, Kenai, Seward, and in the Matanuska-Susitna Valley (Kruse, Zogas, Hard, & Lisuzzo, 2010).

Terrestrial Ecosystems—Vegetation Condition and Trends

Terrestrial ecosystem integrity

The natural range of variation (NRV) is an analysis tool for assessing the ecological integrity of selected key ecosystem characteristics. Perhaps the best available information for understanding NRV in vegetation composition for periods greater than the last 200 years are variations in fossil pollen abundances preserved in peat deposits. The minimum age of the most recent deglaciation in the area of the Chugach National Forest is about 9,000 to 10,000 years (Ager, 2001). Tundra and shrub vegetation developed early, with many species coming from islands of unglaciated terrain within southcentral Alaska. Most boreal forest plants migrated into southcentral Alaska from unglaciated interior Alaska (USGS, 2013). Coastal forest conifers migrated into the area from southeast Alaska (Peteet, 1986).

Local vegetation currently in the Tern Lake area of the Kenai Peninsula developed within the past 2,500 years (Ager, 2001). In the Girdwood area, forests similar to those of today have dominated for at least the past 2,700 years (Ager, Carrara, & McGeehin, 2010). Development of forest communities in Prince William Sound similar to those of today took place during the past 2,000 years (Heusser, 1983). Based on these data, the past 2,500 years may be a useful reference period for evaluating NRV across the national forest.

Baseline studies to describe NRV are rare for the Chugach National Forest. Therefore, only general patterns of historical ecology can be described. An intensive analysis of NRV is not warranted given the limited potential influence of management activities on most characteristics of the terrestrial system. Current vegetation across the national forest is primarily the result of natural processes. Mohatt and Werstak (2012) calculated differences in vegetation indices from 2002 and 2011 satellite imagery. No changes exceeding the monitoring protocol threshold of 20 percent over contiguous areas larger than 4,942 acres were detected.

Romme et al. (2012) summarize a framework for applying NRV concepts to land management. If the conditions of key ecosystem characteristics today are similar to conditions of the past, then there may be no concern regarding the ecological integrity of those characteristics. However, some characteristics that were ecologically common in the past may be socially unacceptable today. For example, the spruce tree mortality associated with the recent spruce bark beetle infestation has resulted in socially unacceptable levels of hazardous fuels accumulation in some areas, even though the outbreak is similar to those seen in the past (see Native Insect and Disease Outbreaks section). Management actions to reduce hazardous fuels are ongoing, especially in the wildland urban interface (Kenai Peninsula Borough, 2004). These treatments result in more socially acceptable ecological conditions, particularly reduced fire risk for a number of years. The treatments also produce ecological features that were rare in the past, including tree stumps, removal of tree boles from forests, and ground disturbance from roads and skid trails.

The expansion of invasive plant populations is one key ecosystem characteristic current condition that was likely uncommon prior to development (e.g., roads, railroads, and trails). Since invasive plants are relatively rare in natural communities of the Chugach National Forest at this time, they likely do not pose an immediate threat to ecological integrity but do pose perhaps one of the larger long term threats if left untended. Climate change could further increase the rates of establishment and spread of invasive plants. Management actions to prevent the introduction and spread of invasive plants and to reduce areas of current infestation are ongoing (DeVelice, Charnon, Bella, & Shephard, 2005).

Changes in vegetation composition and structure have occurred or are occurring within the national forest with effects on terrestrial ecosystem condition. A majority of these changes would be expected based on evaluation of trajectory of the systems as they develop following the last glacial maximum. With current management, there is little direct human influence to the vegetation on about 96 percent of the national forest. Key ecosystem characteristics of terrestrial vegetation are functioning in a way that continues to contribute strongly to ecosystem integrity and sustainability within the plan area.

Terrestrial Ecosystems—Carbon Stocks

Carbon stocks are defined as the amount or quantity of carbon contained in a carbon pool. For the purpose of carbon stock assessment for National Forest System land management planning, carbon pools do not include carbon in fossil fuel resources, lakes or rivers, emissions from agency operations, or public use of National Forest System lands (such as emissions from vehicles and facilities). A carbon pool is any natural region or zone or any artificial holding area containing an accumulation of carbon or carbon-bearing compounds or having the potential to accumulate such substances. Carbon pools may include live and dead above ground carbon, soil carbon including coarse roots, and harvested wood products.

All estimates referenced are in metric units, i.e., hectares (ha), kilograms (kg), metric tons (1,000 kg, denoted t), millions of metric tons (denoted Mt), and t/ha.

Relevant Information

- Live trees in the forests of the Chugach National Forest are currently a carbon sink (store more carbon than they release), sequestering an estimated 150 thousand metric tons aboveground per year. The magnitude of carbon release from the decomposition of dead trees is presently unknown forestwide.
- Compared to the 1999 to 2003 time period, overall aboveground live tree carbon within the national forest increased 4.6 percent during the 2004 to 2010 time period.
- The total carbon pool within the boundary of the Chugach National Forest (excluding carbon in the ocean) is estimated at about 493 Mt (millions of metric tons). There is about 6.5 times more carbon estimated to be belowground (428 Mt) than aboveground (66 Mt). By geographic area, the greatest amount of both belowground and aboveground carbon is estimated in Prince William Sound, followed by the Copper River Delta, and then the Kenai Peninsula.

Aboveground Carbon

Estimates of aboveground carbon in forest trees (Barrett T. , 2014), forest vegetation, shrubland vegetation, and herbaceous vegetation are summarized here. Belowground carbon estimates are at the end of this section.

Forest Tree Carbon

Barrett (2014) provides information on the storage and change of aboveground carbon in live and dead trees within forest vegetation of the Chugach National Forest. The estimates are derived from remeasured inventory plots installed by the Forest Inventory and Analysis (FIA) program. These data primarily represent unmanaged forest conditions as less than three percent of the plots had a record of past silivicultural activity. Excluding the wilderness study area, the carbon stores reported by Barrett (2014) is 98.9 t/ha of forest vegetation. Tree carbon is split as 84 percent live trees, 6 percent snags, and 10 percent downed logs. By geographic area, carbon densities are estimated at 75.2, 103.4, and 118.8 t/ha for the Kenai Peninsula, Prince William Sound, and Copper River Delta, respectively. Barrett (2014) also provides carbon mass information broken down by species and forest type.

In addition, to assess change, Barrett (2014) compares live and dead tree carbon for inventories from two time periods: 1999 to 2003 and 2004 to 2010. There was an overall increase in live tree carbon of 4.6 percent between the two time periods. These figures are equivalent to an annual increase of 0.8 percent, 150 thousand metric tons per year for forest vegetation, and 619 kilograms per forest hectare per year. Also, Andersen (2011) reported that, in white spruce stands on the Kenai Peninsula, about 47 percent of the above-ground carbon in trees is stored in snags primarily killed by the spruce bark beetles in the 1990s.

When carbon is removed from forests through harvest, a portion of the harvested carbon is stored in wood products, often for many decades. Loeffler et al. (2012) estimated carbon storage in harvested wood products (HWP) for the Alaska Region of the Forest Service. The HWP carbon pool is now in a period of negative net annual stock change regionwide because the decay of products harvested between 1909 and 2011 exceeds additions of carbon to the pool through harvest. Total forest carbon, on the other hand, is a function of both HWP and ecosystem carbon, which may have increased in the study area during the study period (Loeffler, et al., 2012).

Forest, Shrubland, and Herbaceous Vegetation Carbon

Estimated carbon stores for forest, shrubland, and herbaceous vegetation in the three geographic areas are displayed in table 30. The forest, shrubland, and herbaceous vegetation groupings are aggregates of NLCD classes (see table 31). Estimates of carbon stores for forest vegetation by geographic area are totals for trees reported by Barrett (2014) plus weighted average totals for other plants (non-trees) in closed and open needleleaf forests in southeast Alaska reported by Mead (1998). The biomass values from Mead (1998) were multiplied by 0.5 to convert to carbon mass. Carbon stores for shrubland vegetation (see table 30) were estimated by weighted averaging totals in tall shrub and low shrub classes reported by Mead (1998). The estimates of carbon stores for herbaceous vegetation were also from Mead (1998). Values from Mead (1998) were further scaled proportionally to the geographic area totals from Barrett (2014).

Use of biomass values from Mead (2000) from southwest Alaska were considered for use in the Kenai Peninsula geographic area estimates but were rejected since they are much less than Kenai Peninsula values in Barrett (2014). For example, the tree carbon stores reported by Barrett (2014) for the Kenai Peninsula geographic area is 75.2 t/ha whereas the tree carbon densities in forest types in Mead (2000) that are also common on the Kenai are all less than 15 t/ha.

Table 30. Estimates of carbon stores (t/ha) rounded to the nearest whole number by forest, shrubland, and herbaceous vegetation in the geographic areas

Vegetation	Geographic Area		
	Copper River Delta	Kenai Peninsula	Prince William Sound
Forest	121	77	105
Shrubland	7	4	6
Herbaceous	1	1	1

Table 31. Aggregation of NLCD classes into the forest, shrubland, and herbaceous vegetation groupings used in the estimation of carbon stocks

Vegetation	NLCD Classes
Forest	Evergreen forest
	Deciduous forest
	Mixed forest
Shrubland	Shrub/scrub
	Dwarf shrub
	Woody wetlands
Herbaceous	Grassland/herbaceous
	Sedge/herbaceous
	Emergent herbaceous wetlands

Table 32 displays estimates of land area and carbon pool by vegetation class and geographic area. The acreage values are area of forest, shrubland, and herbaceous vegetation (from NLCD using the table 31 aggregation) within the outer boundary of the Chugach National Forest. Ownerships within the boundary that are lands of other ownership are included.

Table 32. Land area and estimated carbon pool (Mt) by forest, shrubland, and herbaceous vegetation in the Kenai Peninsula, Prince William Sound, and Copper River Delta geographic areas

Vegetation	Land Area (ha)				Carbon Pool (Mt)			
	Copper River Delta	Kenai Peninsula	Prince William Sound	National Forest Totals	Copper River Delta	Kenai Peninsula	Prince William Sound	National Forest Totals
Forest	122,934	92,783	372,798	**588,515**	14.88	7.14	39.14	**61.16**
Shrubland	249,599	230,728	291,988	**772,315**	1.75	0.92	1.75	**4.42**
Herbaceous	33,993	4,180	5,226	**43,400**	0.03	0.004	0.01	**0.04**
Totals	**406,526**	**327,691**	**670,012**	**1,404,230**	**16.66**	**8.07**	**40.90**	**65.63**

The total amount of carbon held in aboveground vegetation within the boundary of the Chugach National Forest is estimated to be about 66 Mt. Nearly 60 percent of this pool resides in forest vegetation in the Prince William Sound geographic area. As a caveat, it is likely that NLCD is classifying more shrubland to forest than FIA does, so the carbon mass values are probably lower for NLCD forestland than for FIA forestland (Barrett, personal communication, 2013).

Carbon Sink or Carbon Source

Processes that release CO_2 into the atmosphere are called carbon sources, while processes that absorb it are called carbon sinks. A sink absorbs more carbon that it gives off, while a source emits more than it absorbs. The only pool of carbon within the national forest for which carbon sequestration rates have been estimated is live trees. Barrett (2014) indicates that live trees in the forests of the Chugach National Forest are currently a carbon sink, sequestering an estimated 150 thousand metric tons per year. The magnitude of carbon release from the decomposition of dead trees is presently unknown forestwide. The decomposition rate of dead spruce trees (snags and logs) on the Kenai Peninsula is estimated at less than two percent per year (Harmon, Fasth, Yatskov, Sexton, & Trummer, 2005).

Future Trend in Sequestering and Storing Carbon

With existing plan guidance, live trees within the national forest will likely continue to sequester carbon unless there is an increase in large-scale disturbance. The 2002 Forest Plan does not have an allowable sale quantity for commercial timber sales, and there is little harvesting of trees for personal use fuelwood, lumber/house logs, commercial fuelwood, wildlife habitat improvement, and special forest products. Current levels and trends in harvesting timber, fuelwood, and special forest products in the national forest are summarized in the Timber section in chapter 3. Recovery from the spruce bark beetle infestation could be contributing to biomass and carbon increases on the Kenai Peninsula.

The magnitude of potential effects of climate change on carbon pools across the Chugach National Forest is not currently well known. Current understanding, however, suggests that the temperate coastal rainforest, which dominates carbon storage for the Chugach National Forest is unlikely to change dramatically during the next 20 to 50 years. Temperate coastal rainforests rarely experience fire. The trends described previously for carbon sequestration represent a reasonable scenario for trends in carbon sequestration during the planning period within the national forest.

Opportunity to influence trends

The largest pool of aboveground carbon within the Chugach National Forest is in the forests of Prince William Sound (see table 33) and a large portion of this geographic area is in the wilderness study area (see the designated areas and areas recommended for designation map in the map package appendix). The wilderness study area is managed to maintain the wilderness characteristic of the area. Continuing such management of the wilderness study area would likely contribute towards maintaining the large carbon pool in Prince William Sound. Similarly, since 2002 Forest Plan direction limits vegetation management to management area prescription categories 3, 4, and 5 (4 percent of the national forest), continuing such management would likely maintain carbon pools forestwide.

The spruce bark beetle infestation referred to previously has resulted in extensive hazardous fuels accumulation and altered potential for large wildfires (potential source of carbon to the atmosphere). In response to the fuels situation on the Kenai Peninsula, an interagency committee of Federal, state, local, and Alaska Native land managers developed an action plan for fire prevention and protection, hazardous fuels reduction, ecosystem restoration, and community assistance (Kenai Peninsula Borough, 2004). As part of this action plan, mechanical and prescribed fire fuel reduction is occurring on about 100,000 acres (40,468 hectares) of the entire Kenai Peninsula with much of the effort occurring outside the national forest.

Influences on carbon stocks

Biomass and carbon accumulation is a function of environmental drivers, especially moisture, nutrient, temperature, radiation, and disturbance, such as fire, avalanches, landslides, wind throw, floods, and insect or disease outbreaks, interacting with biota. Assessing system drivers and stressors on vegetation is considered previously. Forest Service management has limited capability to affect most of these variables across broad areas. As referred to previously, hazardous fuel reduction is ongoing in response to the spruce bark beetle infestation on the Kenai Peninsula. Much of that fuel reduction involves burning of mechanically piled wood. Such burning is an immediate source of carbon to the atmosphere.

Belowground (Soil) Carbon

Current concerns regarding carbon cycling have focused attention on the role of forests and soils in the storage and cycling of carbon in many key biomes. Carbon accrues in forest ecosystems through photosynthesis and cycles within the system until it is lost through respiration, decomposition, or as dissolved organic carbon. Large quantities of carbon are stored in the soil and forest floor, and soil usually represents a larger carbon pool than above-ground biomass on forest and woodland sites, particularly in northern climes. Soil carbon accumulates in cooler temperate, boreal, and arctic environments. This makes soil carbon assessment more important in those systems. Estimates prepared by the USGS for the conterminous United States indicate that total soil organic carbon storage is 73 PgC (billion metric tons), and total forest biomass carbon is 17 PgC (Sundquist, Ackerman, Bliss, Kellndorfer, Reeves, & Rollins, 2009).

Soil organic carbon includes carbon compounds in the forest floor litter layer, and the mineral soil to a depth of one meter (or depth to bedrock if the soil is shallower than one meter). In the case of organic soils, the entire depth of the soil to a meter or more may be composed entirely of partially decomposed plant materials.

Methods

Soil organic carbon (SOC) was estimated for the Chugach National Forest using data from the NRCS Revised Alaska State Soil Survey Geographic Database (STATSGO, *in publication*).

The input data for soil carbon stock (kg/m^2) was obtained from STATSGO. STATSGO values are based on SOC content determined for each horizon by lab analysis or estimates of SOC based on lab data from similar soils and horizons in a given major land resource area (Nield, personal communication, 2013). Where available, SOC values for a representative soil from map unit components from STATSGO were used to generate SOC values for that particular soil component. These values were corrected for bulk density and coarse fragment content (Nield, personal communication, 2013). This allowed a range of SOC values for all map units identified in the STATSGO map of Alaska, as most soil map units had multiple components. This value is an estimate based on 100 centimeters depth, including the forest floor duff layer.

Weighted averages for the soil map unit components were compiled to calculate carbon stocks. The contribution of any component was dependent on the carbon concentration and the area occupied by the component in the soil map unit. This approach minimized the chance that minor components with large carbon concentrations were not considered within larger areas of small carbon concentration. In a similar manner, the landtype association (LTA) carbon stock was derived from the weighted average of the component soil map unit averages within the LTA.

A GIS exercise was then completed that overlaid and analyzed the STATSGO map of Alaska with the LTAs for the Chugach National Forest. The soil carbon estimates were summarized by LTA. Each LTA has estimated minimum, maximum, and weighted average C content. The total land area in each LTA was multiplied by the average carbon content for that LTA to obtain estimated soil carbon totals by LTA.

Results

Table 33 displays a summary of the soil organic carbon within the Chugach National Forest. Total belowground carbon in the Chugach National Forest, excluding carbon in the ocean is estimated to be 427.6 Mt. By geographic area, the estimated soil organic carbon is 103.04 Mt on the Kenai Peninsula, 217.6 Mt in Prince William Sound, and 121.37 Mt on the Copper River Delta (see table 34).

Table 33. Summary of minimum, maximum, weighted average, and estimated total soil organic carbon zero to 39 inches (zero to 100 centimeters) stored in landtype associations of the Chugach National Forest

LTA	LTA Name	Acres	Estimated Soil Carbon				
			Min	Max	Avg.	LTA Total	percent
			lbs./ac	lbs./ac	t/ha	Mt	
00	Glaciers and Icefields	2,257,583	0.28	87.51	25	22.54	5.1
10	Mountain Summits	1,210,656	0.43	166.40	152	74.44	16.8
30	Mountain sideslopes	1,129,667	0.40	166.40	245	111.94	25.3
40	Depositional slopes	172,757	0.40	166.40	210	14.72	3.3
60	Glacial Moraines	61,659	1.60	87.51	194	4.84	1.1
70	Coastal Landscapes	345,300	0.40	161.41	90	12.55	2.8
80	Fluvial valley bottom outwash	407,920	0.40	166.40	218	36.10	8.2
90	Hills and Plateaus	843,993	0.40	166.40	413	141.40	32
CW	Clear water	46,280	0.55	166.40	191	3.58	0.8
GW	Glacial water	119,830	1.60	166.40	113	5.49	1.2
SW	Ocean salt water	2,989,184	0.40	166.40	12	14.84	3.4
Totals		**9,584,830**	**NA**	**NA**	**NA**	**442.44**	**100**

Note: Acreage figures are derived from the LTA GIS layer and may be different than other acreage values displayed for other resources. All total carbon values are based on present acreage figures.

Table 34. Summary of stored estimated total organic carbon for the Kenai Peninsula, Prince William Sound, and Copper River Delta geographic areas of the Chugach National Forest

LTA	LTA Name	Copper River Delta		Kenai Peninsula		Prince William Sound	
		acres	Mt	acres	Mt	acres	Mt
00	Glaciers and icefields	866,462	8.64	147,933	1.48	1,243,188	12.4
10	Mountain summits	196,933	12.1	407,011	25.02	606,713	37.29
30	Mountain sideslopes	242,541	24.01	367,319	36.36	519,807	51.46
40	Depositional slopes	33,586	2.86	124,141	10.57	15,030	1.28
60	Glacial moraines	47,929	3.77	5,237	0.41	8,493	0.67
70	Coastal landscapes	334,296	12.14	1,513	0.05	9,491	0.34
80	Fluvial valley bottom outwash	328,240	29	45,839	4.05	33,840	2.99
90	Hills and plateaus	116,451	19.48	137,127	22.94	590,415	98.77
CW	Clear water	5,974	0.46	23,773	1.84	16,534	1.28
GW	Glacial water	118,987	5.44	844	0.04	0	0
SW	Ocean salt water	695,622	3.45	55,863	0.28	2,237,699	11.11
Totals		**2,987,021**	**121.37**	**1,316,599**	**103.04**	**5,281,210**	**217.6**

Three LTAs make up 75 percent of the total soil organic carbon storage in the national forest (see table 34). The mountain summit, mountain sideslopes, and hills and plateaus LTAs dominate the carbon storage for the Chugach National Forest. The lowest storage is in clear water LTAs, which have soil carbon storage similar to moraines and glacial water. The soil organic carbon in the water LTAs is derived from map units that contain scrub vegetation, flood plains, and subaqueous vegetation soils. These areas, while not extensive, do contain fairly dense carbon stocks in some cases.

Implications

Forest soil carbon storage is a significant component of the global carbon cycle. Soil carbon is important for sustaining forest productivity. Carbon or soil organic matter (SOM) has numerous interactions with other soil properties and supports essential ecosystem functions (Grigal & Vance, 2000; Jurgensen, et al., 1997; Nave, Vance, Swanston, & Curtis, 2010; Powers, et al., 2005) including:

- Nutrient cycling, by providing sustenance for populations of soil fauna and fungi active in decomposition; nearly all nitrogen and phosphorous in forms available to plants comes from organic matter
- Contributing much of the soil's cation exchange capacity, and binding harmful metals
- Maintaining soil structure, which influences aggregate stability, gas exchange, water infiltration, and storage, buffers fluctuations in soil temperature; aggregate stability and macropore structure help limit compaction and erosion
- Providing specialized microsites with accumulations of SOM required by certain plant species for germination and root development

Carbon compounds are inherently unstable and owe their abundance in soil to biological and physical environmental influences that protect carbon and limit the rate of decomposition (Schmidt, et al., 2011). Large quantities of SOM accumulate in environments, such as wetlands, where the rate of decomposition is limited by a lack of oxygen, and high-altitude and high latitude sites where temperatures are limiting. Globally, about 98.5 percent of the carbon in peatlands is in peat versus about 1.5 percent in vegetation (Gorham, 1991). Peatlands are common within the Chugach National Forest. Forest Service management practices can alter the amount and types of SOM, but because inherent soil or site characteristics sometimes compensate for or mitigate the effects of SOM change, the direct impacts on productivity may be unclear.

Terrestrial Ecosystems—Wildlife

This section describes the wildlife component of the terrestrial ecosystem, including wildlife diversity and system drivers and stressors, for the Chugach National Forest. Key ecosystem characteristics and wildlife conditions and trends are described, ecosystem integrity is assessed, and information needs are identified.

Relevant Information

- The complement of wildlife within the national forest is currently thought to retain the native species, populations, and communities that were here historically.
- The national forest retains all the species, habitats and ecological processes necessary to support a healthy ecosystem. The national forest supports intact ecosystems of sufficient size, quality, and distribution to support historic native species, and few species are currently classified as at-risk.
- Healthy ecological functions still occur, such as predator-prey relationships, pollination, seed dispersal, wildlife movement between patches of habitat, and breeding for the species that live entirely within the national forest.

Terrestrial Ecosystems—Wildlife Key Characteristics

This document uses wildlife, species, and animals as generic terms to describe the mammals, birds, amphibians, and invertebrates that occur within the national forest. Wildlife occurrences, distributions, and communities within the national forest reflect the biotic and abiotic conditions of their landscape. Many of these general characteristics are described in the other sections of this chapter. Wildlife inter-relationships occur at the species, population, community, and ecosystem levels, and function differently depending on the scale and timelines evaluated. Humans are also part of relationships related to wildlife.

In general, many ecological factors that help to describe the ecological integrity of wildlife populations are not well-known (Doak, Gross, & Morris, 2005; MacKenzie, 2005; Morrison, Marcot, & Mannan, 2006; Murray & Patterson, 2006; Peters, Pielke, Sr., & Bestelmeyer, 2004). This lack of data is even more pronounced in Alaska (ADF&G, 2006).

MacDonald and Cook (1996) stated:

> "*For systematists and biogeographers, Alaska remains one of North America's last frontiers…documentation of this complex region's biological diversity remains at the early stages of exploration and discovery. Even for such high-interest animals as mammals, basic information on distribution and taxonomic status has been limited, unfocused or inaccessible, resulting in only broad (Hall 1981; Manville and Young 1965) or popular (Dufrensne 1946; Reardent 1981) treatments…it is even more disturbing that we lack detailed and accurate information for making sound conservation evaluations and wise management decisions.*"

There has been tremendous progress since MacDonald and Cook's (1996) analysis of southeastern Alaska, although important information needs remain (see Information Needs). Technological advances, such as satellite tracking devices, DNA analysis, improved surveillance techniques like Unmanned Aerial Systems and powerful computerized modeling approaches, have been helping to fill these gaps (Morrison, Marcot, & Mannan, 2006; Hegel T. , Cushman, Evans, & Heuttman, 2010).

Diversity and patterns

Fragmentation and connectivity

The ability for animals to move across landscapes is important to maintain regional populations in the short term (Cushman, 2006; Fahrig, 2003) and for animals to shift their range in response to climate change or natural disturbances (Cushman, McRae, Adriaensen, Beier, Shirley, & Keller, 2013; Heller & Zavaleta, 2009). Evaluation of wildlife connectivity varies by species (Keitt, Urban, & Milne, 1997) and needs to be defined functionally (Ament, Callahan, McClure, Reuling, & Tabor, 2014). The patchiness, configuration, and spatial arrangements of habitats in a landscape are important considerations in determining ecological integrity (Keitt, Urban, & Milne, 1997) and need to be assessed at the correct scale: individual, species, population, community, or ecological function to address the objective (Theobald & Hobbs, 2001). Evaluations of wildlife connectivity also need to incorporate appropriate timelines for the question and frame connectivity evaluations in terms of the process of interest (i.e., dispersal, migration, range shifts, and genetic flow).

Connectivity at all scales can be altered by Forest Service management and other human activities. Roads and trails or bare surfaces are barriers to many species but may also provide corridors for animals or organisms well adapted to those cleared areas. Many predators are known to hunt along trails, roads, and powerlines, but impacts from direct contact with vehicles or from increased hunter access can decrease any advantages provided. Corridors or barriers can be created by fish structure installation or removal, mining, roads, trails, utility corridors, or high-use back country trails.

A comprehensive analysis of wildlife connectivity has not been conducted for the national forest; however, there are some obvious patterns. Wildlife species and populations within the national forest are naturally fragmented due to the complex geology, high proportion of islands, barrier mountain ranges, and snow fields. The Copper River Delta is isolated by mountains and glaciers that create barriers to large mammals, such as moose. Connectivity for large mammals may be compromised on the Kenai Peninsula due to the Sterling and Seward Highways, the railroad, developments, and natural topographic restrictions. The Portage Valley in the Kenai Peninsula geographic area is a documented pinch point where big game connectivity is reduced due to both natural topography and human-caused activities. Pelletier et al. (2014) define a pinch point as a narrow corridor where an organism must cross when moving through the landscape.

Many species experience fragmentation within the national forest due to islands, mountains, glaciers, snow fields, and water (see Terrestrial Ecosystems—Vegetation). Isolation from other species, such as predators or competitors, can be an advantage to some species. Fragmentation that restricts the movement of predatory mammals to many of the islands on Prince William Sound has provided shorebirds and marine mammals safe areas for resting and breeding. Many of the larger islands support brown bears but not black bears or Sitka black-tailed deer. Few support wolves. Mink, river otters, weasels, and other predatory mammals have been documented on some islands and bird populations have been affected. Although connectivity associated with islands is reduced for many large mammals, connectivity remains for birds and sea mammals that travel by air or water.

No national forest wildlife populations are thought to be at risk due to isolation or fragmentation. However, the highly dynamic nature of avalanches, earthquakes, and glacial melting, combined with increasing human activity on flatter accessible areas, increases the chances of adverse changes to wildlife movement such that populations may be affected. In general, isolated populations are more susceptible to extirpation.

Populations on islands and in disjointed areas are vulnerable to the introduction of off-site species that could change competition, predator-prey relationships, and habitat conditions. Peters et al. (2004) stated that over-connectedness can also alter ecosystem function by facilitating the spread of pathogenic outbreaks. Over-connectedness can result from Forest Service activities, such as removing barriers for fish, which would allow fish and other organisms into streams previously protected from predation and competition. This can change the aquatic community structure such that native wildlife populations (frogs or invertebrates) might be adversely changed and ecological function compromised. Many islands in

Prince William Sound provide protected habitat for nesting birds, but those birds could be adversely affected if transplants, bridges, or ferry connections provide passage for mammalian predators that otherwise couldn't access that habitat. Over-connectedness can expose wildlife communities to diseases and pathogens for which they have not developed resistance. The 1964 earthquake uplifted dusky Canada goose habitat and made the wetlands more accessible to mammalian predators, predominantly bears. The Forest Service partnered with others to install artificial nest islands to provide dusky Canada geese with protection from the increase in terrestrial predators resulting from the uplift (see At-risk Species).

Species diversity

The Forest Service has not conducted a comprehensive wildlife species inventory, although a national forest bird list was developed by Isleib (1984). Species lists vary depending on the data included by the compiler, so numbers of species on such lists should be used with caution. Some compilers include only species that meet all their life requirements on the landscape being analyzed. Some lists include sub-species and variants (although recent DNA studies and museum research have documented some misidentifications). Others include migrants or part-year residents or non-breeding individuals. Some compilers include accidentals or incidental observations of species out of their published distributional range. These accidentals may include birds that have been blown into the area due to weather. Many species lists use observational data, which can miss cryptic, nocturnal, or obscure species. Other compilers use general habitat or species distribution information that may or may not be field verified. Lists often fail to rigorously evaluate some species, such as amphibians or invertebrates, or include rare, fossorial, and other species that are difficult to locate or identify.

That said, such lists can be useful to highlight general habitat and distributional patterns and can be used to identify apparent range disruptions, local extirpations, or changes to historic information. Comparison of lists and historical observations can point out discrepancies and the need to conduct further surveys and/or do more detailed evaluations. The Alaska Natural Heritage Program (AKNHP) has species compilations by habitats that can be a useful starting point. An August 2013 analysis of wildlife distributions expected within the national forest indicated at least 50 species of mammals should be supported. AKNHP was unable to categorize land ownership, so a broader geographic area than the national forest was used. Mammals were distributed by these broad geographic areas: 46 on the Kenai Peninsula, 43 on Prince William Sound, and 43 on the Copper River Delta. The same analysis for birds indicated that at least 178 species of birds are expected within the national forest: 165 on the Kenai Peninsula, 172 on Prince William Sound, and 159 on the Copper River Delta. Two amphibians occur within the national forest: the wood frog and boreal toad (Ream, 2013; ADF&G, 2006).

By comparison, the Kenai National Refuge (USFWS, 2014a), which is adjacent to National Forest System lands on the Kenai Peninsula and has slightly different habitat types, has a July 17, 2014 species checklist that includes 34 mammals, 154 birds, and 1 amphibian.

Functional redundancy is high within the national forest. For example, there are multiple species of prey, allowing predators to switch prey in times of prey scarcity, and there are multiple browse species, allowing moose to switch food sources to avoid excess toxins. The national forest retains all the species, habitats and ecological processes necessary to support a healthy ecosystem (see the other sections in this chapter). The national forest supports intact ecosystems of sufficient size, quality, and distribution to support historic native species, and few species are currently classified as at-risk. Healthy ecological functions still occur, such as predator-prey relationships, pollination, seed dispersal, wildlife movement between patches of habitat, and breeding for the species that live entirely within the national forest. However, even functional systems need maintenance and monitoring to ensure the risks of natural disturbances, human development within or outside the national forest, and other threats do not change the balance (see Drivers and Stressors).

Wildlife ecological highlights by geographic area

Black and brown bears (Reimchen, 2001), river otters (Ben-Davis, Bowyer, Duffy, Roby, & Schell, 1998), and bald eagles occur in all three geographic areas of the national forest and provide important nutrient transferring functions by moving salmon and other fish to uplands. Moose, deer, snowshoe hares, and other browsing animals influence vegetation by differentially selecting some species over others. Bumblebees and other pollinators occur forestwide.

Landbirds occur across all geographic areas. Landbirds comprise the largest and most ecologically diverse component of Alaska's avifauna and include raptors, grouse, woodpeckers, flycatchers, jays, chickadees, thrushes, warblers, hummingbirds, and sparrows among others (USFWS, 1999; USFWS, 2001). Boreal Partners in Flight (USFWS, 1999) identified nearly 75 percent of Alaska's landbirds as migratory.

Invertebrates also inhabit all geographic areas. They provide services in the ecosystem, such as breaking down materials, recycling nutrients, aerating soil, serving as food for wildlife and fish, and pollinating plants. Invertebrate diversity and occupancy is not well understood or documented. Invertebrates can be influenced by vegetation management or habitat improvement.

Prince William Sound

The national forest provides essential habitat for a variety of sea mammals during pupping and molting season, mostly in the Prince William Sound geographic area. Of particular note are harbor seals. Harbor seals live primarily in marine environments but occasionally haulout on National Forest System lands. Undisturbed island areas are important haulout sites. Tidewater glacial fiords provide protected feeding areas. Sea lions haul out in several areas in the Prince William Sound geographic area (see At-risk Species).

The national forest provides migratory habitat for approximately 5 million shorebirds (Powers, Bishop, Grabowski, & Peterson, 2002), that pass through during the spring and fall, primarily on the Copper River Delta and wetlands within the Prince William Sound geographic area. These important feeding areas are used for a few weeks each spring and fall by flocks of hundreds of thousands of shorebirds (some estimate up to 1.1 million birds). Each flock stays for less than a week during spring migration from late April to mid-May. The birds are able to double their body weight on the insects, small mollusks, and other invertebrates in the intertidal zone during the few days on the Copper River Delta. Those food stores allow the birds to fly nearly non-stop to the northern tundra of Alaska and Canada and begin nesting. Almost the entire North American western sandpiper population, for example, passes through the Copper River Delta during migration. Nesting species include (but are not limited to) dusky Canada goose (see At-risk Species), trumpeter swan, American widgeon, northern pintail, green-winged teal, northern shoveler, red-throated loon, horned grebe, short-billed dowitcher, least sandpiper, greater yellowlegs, common snipe, red-necked phalarope, spotted sandpiper, and semi-palmated plover. Less common Copper River Delta breeders include red-necked grebe, blue-winged teal, dunlin, and lesser yellowlegs. The Copper River Delta supports nearly the entire nesting population of dusky Canada geese (Bromley & Rothe, 2003).

The Prince William Sound geographic area provides important aquatic, riparian, wetland, and estuary habitat for both shorebirds and waterfowl. Islands and standing rocks provide protected habitat for colonial and ground-nesting species. Many of these islands are relatively free of mammalian predators, though some of the larger islands are home to fur-bearing predators introduced by fur-farms from the mid-1700s through the 1950s. Humans can unknowingly trample or disturb nests since many eggs are cryptically colored and difficult to see. Undisturbed beaches are particularly important to nesting birds during the breeding season.

Kenai Peninsula

The Kenai Peninsula geographic area is bordered on the east by a marine shoreline and the Prince William Sound. The upland habitat is a transition zone between coastal and boreal forest and supports the Portage Valley wetland, the second largest wetland within the national forest. The Kenai Peninsula has scattered wetlands and riparian areas, primarily due to high water tables. Important to primary and secondary cavity dwellers, dead trees are common throughout the Kenai Peninsula primarily due to mortality from spruce bark beetles. Wetland and riparian areas provide excellent habitat for waterfowl and waterbirds, including tundra swans and arctic terns. The steep mountains of the Kenai Peninsula provide habitat for Dall's sheep and mountain goats. The Kenai Peninsula also supports brown bears, black bears, wolves, lynx, wolverines, moose, and caribou. Sitka black-tailed deer have been incidentally noted.

Species Diversity

Information available to the Forest Service suggests that the national forest retains all historic terrestrial species, including birds, mammals, predators, and scavengers. There have been distributional, quantitative, and community shifts over time, based on geological disturbances; successional changes; human-caused landscape disturbances, such as the Exxon Valdez oil spill and fire; succession of vegetation; and soil development. Except for a few species, such as dusky Canada geese, wildlife that have been evaluated after the Exxon Valdez oil spill, and some game populations, these changes have not been quantified. There is one species listed in compliance with the Endangered Species Act that occurs within the national forest: the Steller sea lion. The western distinct population segment (DPS) of Steller sea lions is listed as threatened throughout its range, which includes Prince William Sound, and critical habitat is designated within the national forest (see chapter 3). There are no documented changes in the numbers of native wildlife species within the national forest since the 2002 Forest Plan, but species occurrences or distributions have not been thoroughly evaluated. The status of some species has changed (see chapter 3), most notably Kittlitz's murrelet (which was delisted by USFWS as a candidate in the last status review) (see At-Risk Species; see Information Needs).

The abiotic and biotic descriptions in the aquatic, riparian, and terrestrial vegetation sections provide broad habitat information using vegetative types and landscapes. For many wildlife species, however, the Forest Service lacks detailed site- and species-specific habitat association data that would be necessary to define species use, habitat requirements, or habitat deficiencies (see Information Needs).

Extirpations and intended or inadvertent introductions

The complement of wildlife within the national forest is currently thought to retain the native species, populations, and communities that were here historically. However, there have been periods of die-offs, local extirpations, relocations, and intended or unintended introductions. Transplants have been effective in some cases to meet wildlife objectives but also have the potential for unintended consequences. Paul (2009) summarizes wildlife relocations across Alaska and discusses current ADF&G policy on translocations. Specific to the national forest, there have been some noteworthy extirpations, relocations, and introductions.

Woodland caribou (*Rangifer trarandus stoneii*) were present on the Kenai Peninsula (based on available historic records) prior to 1912 when they were extirpated due to a combination of overhunting and habitat loss from human-caused fires (USFWS, 2012a). Little was known of the range and habitat use of these endemic caribou, and they probably were not numerous (ADF&G, USDA, USFWS, 2003). Caribou were reintroduced in a series of translocations from 1965 to 1986. There were five herds established from those transfers, and four remain. The Kenai Mountain herd within the national forest was established as a result of the 1965 translocation (ADF&G, USDA, USFWS, 2003).

Wolves were extirpated from the Kenai Peninsula by 1912, partially due to poisoning, bounties, intentional predator control, reductions in prey due to market hunting, and human-caused fire (Peterson, Wollington, & Bailey, 1984). They were absent for more than 50 years until they recolonized the habitat on their own in the 1960s (Bangs, Spraker, Bailey, & Berns, 1982; Peterson, Wollington, & Bailey, 1984).

Sitka black-tailed deer (Sitka deer) were introduced to Hawkins and Hinchinbrook Islands by the Cordova Chamber of Commerce in several small transplants between 1916 and 1923. Sitka deer swim readily and have moved to other places within the national forest. The Chugach National Forest is the northernmost range for Sitka deer, which are native to coastal southeast Alaska and Canada, generally in old or mixed-age forests less than 1,500 feet in elevation (Paul, 2009). Côté et al. (2004) documented the impacts to vegetation from high populations of deer in similar habitats in southeast Alaska. Selective over-utilization of some vegetative species simplified the forest conditions to the detriment of birds and other wildlife in the system. The impact of introduced deer on islands where they previously have not occurred has not been evaluated. Snow depth, hunting, and weather at the extremes of their distributional range may keep Sitka deer from reaching populations levels that would severely influence vegetation within the national forest.

Wood bison are not native to the Chugach National Forest but are currently pastured at the Alaska Wildlife Conservation Center at Portage (under a special use permit) where the animals are being raised for reintroduction to areas of their historic distribution in interior Alaska beginning in 2015. Wood bison will not be released within the national forest.

Mountain, ocean, and glacial barriers around the Copper River Delta kept moose populations from moving into the area on their own. Moose were introduced to the Copper River Delta in a series of translocations of 23 calves between 1949 and 1958. They have become a highly-desirable meat source for hunters and subsistence users. Moose have influenced vegetation composition and structure in this area, but to date, no adverse consequences to ecological processes or the wildlife community have been observed. Habitat on the Copper River Delta is similar to moose habitat outside the Copper River Delta. The introduction area lies within the overall natural distribution range of moose. A small number of animals were the source of the introductions, but genetic diversity is apparently not an issue in this isolated population. Isolated populations have the risk of in-breeding. Inbreeding increases the chance of adverse genetic modification, leading to poor fitness or survival.

Reindeer were introduced in the western Kenai Peninsula and across Alaska in the early 1900s as an attempt to meet demands of miners for meat and hides (Isto, 2012). The effort on the Kenai Peninsula was unsuccessful for a combination of factors related to economics, logistics, and harsh Alaskan conditions. No reindeer strains are thought to exist within the national forest.

Foxes, primarily non-native silver and blue fox from Europe, were introduced to nearly every accessible island with beach access in Alaska, including those within the Chugach National Forest, starting with Russian fur traders beginning in the 1750s and continuing with commercial trappers as late as World War II (ADF&G, 2006; Isto, 2012; Paul, 2009). Native furbearers, such as mink, marten, beaver, and muskrat, were also moved to islands where they did not naturally occur (Paul, 2009), and prey species, including rabbits and rats, were also moved to islands in order to feed the introduced fur bearers. This practice continued during territorial days with considerable impact to native wildlife on the islands where these predators did not previously exist. The last fur farm permitted within the national forest was in the early 1900s (Isto, 2012). Most fur farms were abandoned in the 1930s and many foxes died from disease and starvation. The long-term ecological consequences of the fur farm era have not been evaluated for the national forest.

Mink were transplanted to some islands that are now part of the national forest, including Naked Island. It is unknown if mink were already present at the time (Irons, Bixler, & Roby, 2013). Their high predation rates on pigeon guillemots documented by Irons (2013) on Naked Island are similar to the predation rates on bird islands in Europe where mink were introduced (Bonesi & Palazon, 2007; Nordstrom, Hogmander, Laine, Nummelin, Laanetu, & Korpimaki, 2003). USFWS partnered with APHIS and the Forest Service to reduce the number of mink on Naked Island to help recover pigeon guillemot populations. Pigeon guillemots were adversely affected by the Exxon Valdez oil spill.

No intentional introductions have occurred since the 2002 Forest Plan was approved, but inadvertent introductions have been reported with increasing frequency since then as noted. The extent and degree of these unintentional introductions have not been rigorously quantified in most cases, nor are the consequences of their addition to the ecosystem fully known. Animal invasions occur in both aquatic and terrestrial environments.

In the terrestrial environment, relatively few animal species were considered highly invasive or threatening to ecosystem health and integrity in a review conducted in 2005 (Schrader & Hennon, 2005). Gotthardt and Walton (2011) conducted a more recent analysis. The Forest Service has not done surveys for invasive or non-native wildlife, but some species evaluated by Schrader and Hennon (2005) and Gotthardt and Walton (2011) have been confirmed near the national forest. Because these species are primarily found in association with human habituation, Anchorage, Girdwood and the other small communities within or adjacent to the Chugach National Forest provide greater potential for range expansion, and their presence on parts of the national forest is likely.

Gotthardt and Walton (2011) evaluated 23 invasive animal and aquatic species known to occur within Alaska's national forests and provided invasiveness scores. Ten mammal and bird species were evaluated and ranked in terms of invasiveness and only two species, the Norway rat and house mouse, were categorized as high risk invasive species (Gotthardt & Walton, 2011). Norway rats have been enormously detrimental in coastal ecosystems where they are responsible for severely reducing or extirpating native ground nesting seabirds, burrow nesting seabirds, and shorebirds (Ebbert & Byrd, 2002; Kurle, Croll, & Tershy, 2008; Major, Jones, Charetted, & Diamond, 2006).

No surveys have been conducted within the national forest for non-native earthworms and none have been confirmed, but they have been documented within the nearby Kenai National Wildlife Refuge (Saltmarsh, 2012) and are likely to also occur within the national forest. Saltmarsh found that 90 percent of road sites and 80 percent of boat launches (of a total 70 sampling sites) contained earthworms, and 50 percent of low human impact sites were occupied. She concluded that road use and construction and abandoned bait may be mechanisms for earthworm introductions within the wildlife refuge. Roads, boots, topsoil, and equipment can transport earthworms or their eggs. Costello et al. (2011) documented that earthworms spread rapidly in logged areas of the Tongass National Forest. Earthworms submerged in water can remain viable for up to six days, making streams a vector for their spread (Costello, Tiegs, & Lamberti, 2011). They can also remain viable for a certain time in the guts of fish. Use of earthworms as bait is another likely vector and could be one of the main concerns for the national forest, which has few roads or other means for earthworm transfer.

Earthworms introduced in this part of Alaska are primarily from Europe or Asia. An earthworm native to the Queen Charlotte Islands in British Columbia has been documented in southeast Alaska, but it is unknown whether the species moved 124 miles (200 kilometers) north on its own or was transported by humans. Recent literature describes the harmful effects of earthworms in habitats where they did not previously exist (Bohlen, et al., 2004; Costello, Tiegs, & Lamberti, 2011). Earthworms accelerate the decay of leaf litter and may change nutrient cycles and soil characteristics such that plant and invertebrate communities change and biodiversity declines.

Garter snakes have been documented in the Chugach State Park adjacent to the Chugach National Forest.

Feral cats can be devastating to native bird and small mammal populations. They are common in communities adjacent to and could occur within the national forest, but they have not been confirmed.

Once invasive/non-native animals become commonly reported, they are often too established on the landscape to control. The Forest Service has an active invasive plant control program for the Chugach National Forest, but has no similar program for the control of non-native wildlife or invasive organisms.

Terrestrial Ecosystems—Wildlife Drivers and Stressors

The processes that affect wildlife individuals, species, populations, and communities are complex and interactive. All animals compete for food, mates, and space. Each species requires a range of conditions that will provide them with the food, shelter, breeding, and dispersal conditions they need to survive and reproduce. Reduced fitness, curtailed reproduction, or mortality can result at the individual, population, or community scale if the amount, quality, or accessibility of essential habitat requirements are lacking.

The habitat parameters required to support wildlife are different for each species and for different life-stages (e.g., breeding, denning, winter range, etc.). The suite of biological and physical parameters necessary to support life history requirements for each species can be described as a habitat association. Habitat associations can be used to assess the occurrence and distribution of a species. Analysis of habitat quantity, quality, and distribution can help determine if and how management actions might affect the status and trend of that species or habitat. Habitat associations often include parameters that have been described in the aquatic, riparian, wetland, and terrestrial vegetation sections but also require details, such as vegetative species, successional stage, microhabitats, temperature, water availability, structural components, branches of a certain size, and special features, such as cavities or holes. Some of these parameters are not always measured in enough detail to define that vegetative/physical type as habitat for a particular species.

Not all habitats and habitat components are equally important. Nor do all wildlife life requirements equally influence survival and reproduction. There are several phases of life and seasons when wildlife is particularly vulnerable to habitat loss, disturbance, or community imbalance. Reproductive, migratory/dispersal, and wintering habitat are three of the most essential habitats influencing fitness, survival, and reproduction.

Birthing/young rearing

The sensitive time for giving birth and raising young can be predictable for many species and the most vulnerable time is fairly short. During this crucial period, parents generally have limited mobility and high energy demands as they need to feed their young and themselves and provide protection from predators or competitors. They are generally restricted to small areas until the young are able to move more freely. Protecting the small areas around nests, dens and other important rearing areas when animals are most vulnerable can help ensure successful reproduction.

Winter habitat

Times of severe weather and low food supplies within the national forest are usually during winter for most species. Generally, winter is stressful for wildlife. Snow, ice, cold, and winds can make travel difficult, energetically costly, or impossible. Leaves on trees and branches that would provide cover and security from predators have been shed. Vegetation dies in winter or becomes dormant or snow-covered. It no longer provides nutrients necessary to maintain body weight. Most big game animals survive the winter starvation period by going into the dormant season with fat accumulated during the summer when food is more plentiful. They typically alter their food source.

Caribou, for instance, switch from succulent shrubs and forbs to lichens because they maintain some nutritional value during dormant periods. Caribou in the Kenai Mountain herd typically move to higher elevations in winter to avoid predators and take advantage of wind-swept ridges.

Moose switch from leaves and forbs to branches. They don't gain significant energy from such marginal food sources, but it reduces the degree of weight loss. Many plants defend themselves by going dormant and developing toxic compounds. Browsers compensate for the toxic properties in plants by switching species often during the season. They can tolerate a certain level of tannins, but must find other species to avoid significant adverse effects. Therefore, a wide variety of food plants within the winter range is important to maintain browsers over winter.

Bears, for instance, will go into a period of hyperphagia in the fall. They can ingest more than 20,000 calories a day to gain enough fat to carry them through the winter denning period. Interestingly, a survival strategy of bears is to give birth in the dens during estivation and winter. Cubs can nurse in the dens, protected from other bears and predators, until they grow enough to be somewhat mobile when their mother emerges from her den a few months later.

Predators and furbearers often benefit by feeding on vulnerable prey species or animals that have died due to starvation or weather. They are also impacted by the temperatures and constrained movement. Much of their energy goes to the development of thick fur coats to protect them from severe temperatures and winds. Furbearers are targeted by trappers and hunters in winter who seek to harvest them when their fur is in this prime condition (see hunting/trapping).

Moose, Dall's sheep, mountain goats, deer, and most other wildlife try to maintain the body fat essential for their survival through the winter by reducing movement, finding shelter from winds and cold temperatures, and avoiding disturbance. Amphibians survive by burrowing into mud and going dormant. Bears estivate (a type of hibernation) in dens, and do not eat for months. Many birds and whales migrate thousands of miles to find better food sources. Winter recreational activities can have significant impacts to wildlife in winter by causing them to burn extra calories to avoid or tolerate people and activities. Activities that change habitat accessibility can be both advantageous or harmful depending on the extent of the activity on the landscape, the timing and degree of use on that trail, the amount of time people are using the trail (skiers take a longer time to cover the same ground as a snowmobile), and the species. Moose may use snowmobile and ski trails for easier movement through their habitat. Wolves also use these compacted areas for access to moose. Animals can be attracted to roads and railroads for easier movement, but suffer high mortality from car and train collisions (see Disturbance).

Dispersal/migratory habitat

Young animals that leave their birthing area and fend for themselves for the first time are extremely vulnerable. Mortality exceeds 50 percent in studies of post-fledging birds. Post-fledging survival in raptors can be less than 25 percent. The availability of accessible prey at the time of fledging is an important factor related to post-fledgling survival. For instance, for goshawks, Weins et al. (2006) suggested that management practices that provide abundant prey while concurrently providing forest structural conditions to allow goshawks to access prey within their breeding areas should benefit juvenile survival.

Migratory habitat is particularly important in the Copper River Delta geographic area for shorebirds and waterfowl. The migratory season is very short, but the habitat provided by the Chugach National Forest is essential to the survival and reproduction of many of these animals.

Competition occurs among animals of the same species and among different species. Animals compete for food, cover, and mates within the same species, and different species compete for limited resources.

They make energetic trade-offs between protection from predators and other competitors, finding food, or seeking mates. Different species (or individuals) practice different adaptive strategies to make them successful at surviving and reproducing. They follow different strategies that allow them to use their environment and adapt to changes, whether that be natural disturbances such as those typical within the national forest (avalanches, floods, earthquakes, fire, drought, weather extremes, deep snow, or excessive temperatures), or disturbances related to human activities.

Wildlife populations within the national forest are still influenced by natural predator-prey inter-relationships. The reduction of predators in much of the United States has altered this natural ecosystem process for many national forests in the contiguous 48 states; this has largely not occurred on the Chugach National Forest. An example of a natural predator-prey relationship is lynx and snowshoe hare. They are cyclic in their response to populations of each other. When snowshoe hares become too numerous, they can over-utilize their food supply and concurrently cause increases in lynx populations. Over-hunting by lynx and starvation in snowshoe hares decrease snowshoe hare populations and lynx populations crash in response. Lynx will move far out of their typical range, and many will die. Fewer snowshoe hares allow vegetation to recover. Snowshoe hare reproduction increases with the increase in food and reduction in predators and the pattern repeats.

Environmental stressors

Stressors include avalanches; earthquakes; floods/tsunamis; drought and other extreme weather events (high snow, snow of unnaturally long duration, excessively high or low temperatures, winds); changes in normal weather patterns that bring precipitation or temperature changes during vulnerable periods (such as nesting); and epidemics (e.g., rabies and insect infestations). The locations, size, patterns, intensity, and frequency of most of these natural environmental disturbances are described in other sections of this assessment. The wildlife communities currently present within the national forest reflect their historic ability to adapt to these natural disturbances. Small scale extirpations (local extinctions) can (and have) occurred on a temporal scale, but if a source population is nearby and connectivity is adequate to facilitate their dispersal, the affected wildlife populations or communities can recover. Impacted wildlife can emigrate to more favorable habitat and possibly recolonize the disturbed area after it recovers.

Hunting and trapping

Hunting and trapping are important human-related drivers of wildlife populations (see chapter 3). ADF&G and the Federal subsistence program follow principles of sustained yield, and most hunting/trapping is designed to be compensatory (rather than additive) to natural mortality. Harvest that intentionally or inadvertently over-utilizes females can have significant impacts on populations. High female harvest can have the greatest impact on species with low reproductive rates like black and brown bears, Dall's sheep, and mountain goats, but harvest of females can also be a management tool to quickly reduce overpopulation. Overharvest of males can result in low male to female ratios resulting in less-successful reproduction; this has been a recent concern resulting in moose hunting regulatory changes on portions of the Kenai Peninsula. Determining sex of some species can be difficult in the field. It can take many years for a population/herd to recover from the overharvest of females in species with low reproductive rates. Another stressor related to harvest is unreported/illegal kills (poaching). ADF&G biologists usually estimate unreported kills in their management reports as a safety measure so hunting quotas do not exceed sustainable levels. Habitat loss, degradation, and conversion are primary stressors related to human use. Habitat loss is not only the loss or degradation of vegetation or space within a development footprint, but also may include disturbance factors or barriers that preclude wildlife from accessing habitat across a much larger area. Changes to habitat can alter the wildlife using that habitat, making it more suitable for some species with inadvertent impacts to others. The ecological consequences of vegetative changes can be reduced when the interactive effects are fully considered and mitigated. The

Forest Service has a staff of interdisciplinary specialists who are trained to evaluate management treatments at various scales, using available information and resources.

Vegetation treatments have affected a relatively small portion of the national forest, but many have occurred in accessible areas that may also be relatively more important to wildlife. As such, those impacts may have a higher impact on the ecological integrity of wildlife than the percentages suggest (see chapter 3).

ADF&G (2006) provides a partial summary of risks that are particularly relevant to Alaskan wildlife habitat, populations, and communities related to human activities. The lack of information and analytical tools is one of the biggest challenges to maintaining ecosystem integrity (ADF&G, 2006). Alaska shares the world-wide challenge of protecting and conserving natural biotic communities and ecologic function with increasing human use (ADF&G, 2006).

Human-caused fire

Most Chugach National Forest wildland fires occur within the Kenai Peninsula geographic area during spring or late summer when fuels are driest. The Copper River Delta and Prince William Sound geographic areas are usually too wet to support fire. The spring dry season for the Kenai Peninsula is during the breeding season for many wildlife species. Fires on the Kenai Peninsula geographic area from 1914 to 1997 (Potkin, 1997) converted older forest to earlier seral conditions. The younger vegetation was favored by moose, but only after burned vegetation began to re-sprout. The fires killed many of the larger trees and destroyed lichens, temporarily modifying breeding habitat for forest land birds and reducing winter food for caribou.

Introduced, nonindigenous, and invasive species and diseases and pathogens

Nonindigenous wildlife within the national forest is described in the diversity section. Introduced and invasive species increase the risk of exposure to diseases and pathogens that can directly kill large numbers of animals or reduce fitness to the extent that populations can decline or even become extirpated.

Diseases and pathogens influence the health of individuals and sometimes populations. The Chugach National Forest is currently free of three serious pathogens that are severely affecting other parts of the world. The H5N1 HPAI avian flu was first noted in commercial waterfowl production areas in Asia. It has spread and adapted to cause illness and death in domestic and wild birds and occasional mammals, including humans. As of 2013, no HPAI has been documented in Alaska.

Another severe wildlife pathogen is white nose syndrome (WNS), a fungal infestation (*Pseudogymnoascus destructans*) of primarily cave-dwelling bats. First documented in 2008 in the northeastern United States, the pathogen has affected more than 55 million colonial bats in the eastern half of the United States and has spread as far west as Oklahoma as of June 2013. WNS has not been documented in Alaska. The Chugach National Forest has one documented bat species, the little brown bat. WNS has continued to expand west and north from the east coast (USGS, 2014b).

West Nile virus (WNV) is a pathogen that can cause disease in both humans and animals. ADF&G reported that 200 human deaths have occurred from 4,000 human cases nationwide. Horses and certain birds are particularly vulnerable to observable illness or death. It was first detected in the western hemisphere in New York in 1999 and is spread by certain types of mosquitoes. The virus is viable in a bird for a short period of time. The relationship between birds coming from infected areas and their exposure to Alaska mosquitos suggests that WNV could be spread locally only by the appropriate mosquito species. These species are currently not common in Alaska.

Pathogens are a major cause of worldwide amphibian declines (Wake & Vredenburg, 2008). One of the most serious is the aquatic fungus *Batrachochytrium dendrobatidis* (BD), otherwise known as chytrid, which has been linked with extirpations of boreal toad populations (Hossack, Lowe, Ware, & Corn, 2013). Fragmentation and drought can magnify the spread of disease by increasing the density of hosts and increasing transmission rates (Hossack, Lowe, Ware, & Corn, 2013). Chytrid fungus has been documented in wood frogs on the Kenai Peninsula (MacDonald, 2010). Growth abnormalities in wood frogs have also been documented: 7.9 percent of individuals on the Kenai Refuge had abnormalities (Reeves, Batrachochytrium dendrobatidis in wood frogs (Rana sylvatica) from three national wildlife refuges in Alaska., 2008b), and abnormalities were correlated with proximity to roads, suggesting chemical contamination or possibly that roads may be facilitating predators, parasites, or pathogens (Reeves, Road proximity increases risk of skeletal abnormalities in wood frogs from national wildlife refuges in Alaska, 2008a).

Dall's sheep are highly susceptible to *Protostrongylus stilesi*, or sheep lungworm, carried by domestic sheep and goats, including those used as pack animals (Kutz, Hoberg, Nagy, Polley, & Elkin, 2004). The pathogen is lethal to sheep. Pneumonia epizootics have caused the extinction of many populations of closely related bighorn sheep (Wehausen, Kelley, & Ramey, 2011). The risk is so significant that ADF&G (2014a) has restricted the use of domestic goats or domestic sheep as pack animals while hunting sheep, mountain goat, or musk ox. The restriction does not apply to recreational use. Forest Service management could help prevent exposure by building in restrictions related to the use of pack animals within the national forest.

Invasive species often hitch a ride on cargo, boats, planes, and boots that have been to infested areas. Coordinating with other agencies to inspect and clean vehicles, sterilize of boots and waders, implement immediate eradication treatments when new invasive species are reported (before they get established), and educate staff and the public about identification and risks can be effective in helping manage invasive species.

Pollution, pesticides, and chemical spills

Human generated waste is accumulating worldwide at increasing rates. In marine ecosystems, plastics are the most significant waste product affecting species. Plastics account for 60 to 80 percent of marine debris (Derraik, 2002). Most of the plastic waste in Alaskan waters is from fishing debris (Hess, Ribic, & Vining, 1999). In March 2011, a tsunami resulting from a powerful earthquake in Japan washed vast quantities of debris into the Pacific Ocean. An aerial survey of marine debris in Prince William Sound was conducted by NOAA in 2012. The survey found a range of marine debris density along the shoreline.

Among tsunami debris are appliances, shipping containers, docks, boats, tires, fishing gear, building supplies, unlabeled chemicals, and parts of buildings. Nets and fishing debris can snag or entangle wildlife leading to injury and sometimes death. Perhaps the most damaging tsunami debris is the plastic building foam and various types of Styrofoam. The foam and plastics are compounds that do not break down into harmless organic materials. Instead, they break into smaller and smaller particles and are often ingested by birds and invertebrate organisms. Foam particles are non-digestible and can lead to an animal or bird starving with a stomach full of plastic. Plastics also contain polychlorinated biphenyls (PCBs), thought to contribute to reproductive abnormalities, death, increased disease and/or disruptive hormone levels (Derraik, 2002).

Wastewater effluent commonly discharged from domestic and industrial sources, known as point-source pollution, impacts aquatic life and the terrestrial species that depend on them as food sources (ADF&G, 2006). Pollution can affect any life stage, leading to increased mortality and reduced reproduction and growth. Domestic wastewater sources include community septage and sewage, wastes from oil and gas development, mining, seafood processing, timber harvest, run-off from roads and utility corridors, and effluent from cruise ships and boats (see Aquatic). Nonpoint source water pollution is the primary cause of water pollution in Alaska according to ADF&G (2006).

Pesticides include fungicides, insecticides, herbicides, rodenticides, piscicides, sanitizers and disinfectants, wood preservatives, pet products, biocides, mosquito repellents, bear deterrents, marine anti-fouling materials, paints, etc. (ADF&G, 2006). All pesticides sold in Alaska must be state and EPA registered. Pesticides are important for many reasons and are an effective tool to kill invasive weeds that threaten wildlife habitat. Pesticides can harm or kill birds and mammals if they ingest granules, baits, or treated seeds, consume treated crops, drink or use contaminated water, feed on pesticide-contaminated prey or are directly exposed to spray. Long term exposure to pesticides can lead to reproductive failure, deformities, and changes in behavior that can be difficult to detect. DDE was linked to severe peregrine declines in Alaska several decades ago. Although DDT has been banned and peregrines have rebounded, DDE and DDT can still be detected in Alaska (Anthony, Miles , Estes, & Isaacs, 1999; Rocque & Winker, 2004). Pesticides that are banned in the United States are still routinely used in wintering areas of Alaskan migratory birds (ADF&G, 2006). Newer pesticides are available that have short bioactive lifetimes, are specifically targeted to the defined use, and are applied with careful mitigations. It can take considerable investment to choose pesticides with minimal non-targeted impacts, but the results can be more favorable to wildlife likely to be in the treatment area. Garbage and discarded human waste is a problem for terrestrial species and ecosystems as well. Use of bear-resistant dumpsters is encouraged in the vicinity of the national forest. Fish waste from the Russian River during salmon runs is an attractant to bears, eagles, and other wildlife species. Bears and a wide variety of other species, including moose, gulls, ravens, jays, furbearers, and rodents, will seek out and eat human foods. Entrapment from plastic six-pack can holders, narrow mouthed bottles, discarded fishing line, and other debris can cause injury and death. The rapid habituation of bears to human foods can result in bear-human encounters and safety problems. Populations of ravens, gulls, and eagles can become more numerous around such artificial food sources, changing the natural predator prey-balance (Powell & Bacensto, 2009; Weiser, 2010).

Wildlife, particularly in the Prince William Sound geographic area, was affected by the 1989 Exxon Valdez oil spill. The 1994 Exxon Valdez Oil Spill Restoration Plan (EVOS Trustee Council, 1996) described the dozens of species and services affected by the spill and identified recovery objectives that needed to be met for each of the species and services in order for them to be classified as recovered. The Exxon Valdez Oil Spill Trustee Council facilitated millions of dollars of research, monitoring and restoration/recovery projects since the spill to help recover species that were injured.

Progress toward restoring ecosystems to pre-spill conditions has been made. Monitoring, restoring, and improving resources affected by the spill is ongoing. Some lingering oil remains on the landscape in subsurface beach habitat. The USDA Forest Service is an active member of the Exxon Valdez Oil Spill Trustee Council. Table 35 displays the most recent recovery status of species and services (EVOS Trustee Council, 2010). In late 2014, the Exxon Valdez Oil Spill Trustee Council re-evaluated the status of species and services injured by the oil spill. An updated list will be posted online.

Table 35. Overview of the status of injured resources and services monitored in the Exxon Valdez Oil Spill Restoration Plan (EVOS Trustee Council, 2010)

Resource	2010 Status
Archaeological resources	Recovered
Bald eagles	Recovered
Barrow's goldeneye	Recovering
Black oystercatchers	Recovering
Clams	Recovering
Common loons	Recovered
Common murres	Recovered
Cormorants	Recovered
Cutthroat trout	Very likely recovered
Designated wilderness areas	Recovering
Dolly Varden char	Recovered
Harbor seals	Recovered
Harlequin ducks	Recovering
Intertidal communities	Recovering
Killer whales-AB	Recovering
Killer whales-AT1	Not recovering
Kittlitz's murrelets	Unknown
Marbled murrelets	Unknown
Mussels	Recovering
Pacific herring	Not recovering
Pigeon guillemots	Not recovering
Pink salmon	Recovered
River otters	Recovered
Rockfish	Very likely recovered
Sea otters	Recovering
Sediments	Recovering
Sockeye salmon	Recovered
Subtidal communities	Very likely recovered
Human service	2010 Status
Commercial fishing	Recovering
Passive use	Recovering
Recreation and tourism	Recovering
Subsistence use	Recovering

The Forest Service acquired lands at Knowles Head near Cordova with money from the Exxon Valdez oil spill settlement. Acquired lands are to be managed with the goals of maintaining the land in perpetuity for the maintenance of conservation values and restoring or enhancing injured resources. Conservation values include the amenities and attributes of natural resources, including fish and wildlife habitats.

Increased human access, roads, railroads, trails, and motor vehicle recreation

Development and infrastructure, including roads, dams, mines, powerlines, and developed recreation sites affect wildlife movement and use of habitat. Developments can remove or alter habitat and displace animals from essential areas. The design of developments can create inadvertent mortality hazards. For instance, windows in buildings are one of the greatest contributors to bird mortality worldwide. Communication towers, high tension wires, wind turbines, and uncapped pipes on developed facilities can also kill birds (USDA, 2005).

Many species of birds, especially the small insect-eaters, migrate at night. Migrating and nocturnal birds use the light from the moon and stars and the setting sun for navigation during migration. Light pollution hides their navigational aids and can pull birds off track, contributing to increased mortality. There are places adjacent to the national forest, such as Anchorage, Girdwood, Cordova, Whittier, and infrastructure along roads that have altered habitat in ways that likely influence wildlife movements, behavior, and survival.

National forest habitat loss has resulted from development, including mines, powerlines, roads and trails, railroads, cell towers, dams, buildings, trails and cabins, and vegetative treatments as described elsewhere in this Assessment.

Although developments and altered habitat make up a small proportion of the total area of the national forest, they tend to concentrate along riparian areas and shorelines, and in flatter, more accessible areas. These flatter and more accessible areas tend to be the most important and productive habitats for wildlife and plants. The direct loss of habitat is a relatively small percent of national forest area but is thought to be a much larger proportion of suitable habitat for many species.

Mitigating known risks and incorporating habitat enhancement opportunities should be considered when planning new developments. Developments and infrastructure can enhance habitat for some species by creating missing habitat components, such as snags, down wood, and nesting platforms. Similarly, a development that increases availability and access to human food or other attractants may contribute to localized population increases of nuisance wildlife. Implementing thoughtful wildlife design criteria can reduce potential for unwanted outcomes.

Disturbance, displacement, habituation, and behavioral stressors

The behavioral response of wildlife to disturbance is a major driver affecting populations and communities. It is one of the stressors most likely to be influenced by Forest Service activities. Disturbance can be noise, activity, vibrations, colors, light, or shadows. The intensity, duration, severity, and frequency of disturbance are factors that affect the significance of the disturbance. Seldom is there an accurate evaluation of the intensity, duration, severity, or frequency of disturbance events.

Animals often respond most directly to the types of disturbances that cause (or could cause) them harm. The significance of animal response to disturbance is influenced by the fitness, age, and reproductive state of the animal when they are disturbed, the availability of suitable habitat outside the disturbed areas, the season of year, and the tolerance of that animal to the disturbance. Response can take the form of avoidance. Avoiding essential habitats can be detrimental to fitness, survival, and recovery. Animals may flee an activity perceived as harmful. Fleeing is an energetic cost that can be harmful to the survival of an animal and that can make them more vulnerable to predators. Moving from familiar territory into unknown territory increases chances of predation or competition with other animals already present. If the fleeing and avoidance significantly reduce the time an animal spends feeding itself or its young or prevents an animal from resting to retain body fat, survival and reproduction will be reduced.

Animals may also respond aggressively to perceived threats and disturbance by attacking or charging. For instance, brown bears with cubs may attack hikers and recreationists if they are surprised and if they perceive the actions of the person(s) as harmful. Moose cows may attack by slashing with their hooves if they are disturbed. When humans defend themselves against such attacks, the animal is often killed, and any young-at-side are orphaned to die later.

The behavioral response of wildlife to stimuli is complicated by a tendency of some animals to habituate to that activity. Habituation occurs when an animal is repeatedly exposed to stimuli where no direct harm results. Habituation is more likely to occur if the timing, location, and frequency of the disturbance is predictable. Habituation is a coping mechanism that can be helpful to an animal by allowing them to tolerate activity that would otherwise cause them to flee or react. If an animal can habituate to a stimulus that leads to no harm, the energetic effect of that disturbance is reduced significantly. Habituation can be harmful in the case of bears that learn that people are often associated with food and perceive that food can be obtained without harm to them. They lose their natural avoidance behavior around people and can start approaching people in dangerous ways. Bears at the Russian River are attracted to fish waste, garbage, and other human-related food sources such that their behavior changes and they become habituated. Habituated animals are still wild and can be dangerous. If animals are killed because of habituation to human food, those areas can become mortality sinks, sometimes to the extent that population levels are affected at a broader scale.

Food conditioning is the term that describes changes in an animal’s normal behavior caused by their attraction to human food sources. Food conditioning can occur in most animals. Garbage and fish waste can cause unnaturally high concentrations of gulls and eagles. Domestic crops or landscaping/road byways can be attractive to moose and cause them to move into areas they would normally avoid. Habituation to traffic can lead an animal to have a false sense of security when crossing roads and mortality can result if they misjudge traffic. Some stimuli are so intense that animals seldom habituate. Blasting and sonic booms are examples that many wildlife cannot tolerate without high stress response.

Disturbance response is often not clearly observed. An animal may experience high agitation due to noise or activity such that their heart and breathing rate are accelerated, stress hormones are abnormally elevated for extended periods of time, or high energy is spent on hyper-alert behavior. An outside observer might see the animal standing calmly and not realize that the animal is experiencing stress. The costs of such chronic stress may have direct links to survival and fitness. The effect of chronic stress is gaining more research and consideration, because it can be deleterious on individuals and wildlife populations.

Some aspects of disturbance can be easily mitigated or avoided. Examples include:

- Planning activities outside of sensitive seasons (particularly breeding and wintering)
- Avoiding essential habitats when susceptible wildlife are present
- Concentrating disturbance to smaller footprints on the landscape
- Making non-harmful disturbances more predictable (to encourage healthy habituation)
- Ensuring refugia habitat is nearby when disturbance activities are likely to cause an animal to avoid essential habitat or flee from disturbance
- Buffering noises, vibrations, or color

Climate change

A 2004 Arctic Climate Impact Assessment (ACIA) report summarized projected climate change impacts on systems. Wetlands and bogs are drying in boreal landscapes and this effect is likely to accelerate. Boreal toads, wood frogs, freshwater shorebirds, and aquatic invertebrates and are particularly vulnerable to this change. Precipitation may increase along marine shorelines, and weather predictability is changing. Melting glaciers and ice fields are likely to improve connectivity, creating interactions between organisms that may lead to increased risk of disease and pathogens and significant changes to historic competitive and predator-prey relationships. Ocean salinity and pH are already changing, and influencing the marine environment which is important to many birds, sea mammals and predators. Forage fish populations have declined in Alaska, and impacts to animals dependent upon them are already being noted (see Aquatic - Fish). Species ranges are projected to shift northward on both land and sea. Insect infestations have occurred on the Kenai and fire risks have increased (see Terrestrial-Vegetation and Fire) which may be influenced by climate change.

Information Needs

Available information on wildlife in Alaska focuses on game species and economically important fish species. Migratory landbirds, raptors, shorebirds, and waterbirds have the greatest amount of data of all taxa evaluated (ADF&G, 2006). There is limited scientific information on the non-game wildlife of the Chugach National Forest, including invertebrates, amphibians, fish, birds, and smaller mammals.

Invasive and non-native animal presence within the national forest is not well-documented and therefore is difficult to evaluate in terms of risk or need for control.

Preferred or essential habitats of nongame species are generally uncharacterized in Alaska, so meaningful habitat models cannot be developed, especially at the national forest level. Distributions of many small terrestrial mammals remain unknown except for anecdotal information and isolated studies in localized areas. There is a need for genetic relationships among island endemics and their taxonomic status in order to evaluate long term functional connectivity. Models based on adequate land cover information may be the best approach to gain some of this information.

Detailed habitat use regarding water quantity needs and dispersal pathways for amphibians within the national Forest have not been documented. Amphibian distributions currently rely on anecdotal information in most cases.

There is an absence of general and site-specific knowledge about terrestrial invertebrates. The habitat use and distribution of most species remain unknown except for anecdotal information and small localized studies.

At Risk Species—Threatened, Endangered, Proposed and Candidate Species

In Alaska, the USFWS and the National Marine Fisheries Service (NMFS) share responsibility for implementing the Endangered Species Act of 1973 (16 USC 1531 et seq.; 50 CFR 226.202) and the Marine Mammal Protection Act of 1972 (16 USC 1361). Each agency has responsibility for discreet taxa. A current list of federally listed species relevant to the plan area and planning process was obtained from the regulatory agencies (NMFS, 2013i; USFWS, 2012c).

This section reviews information regarding the ecology and distribution of federally recognized threatened, endangered, proposed, or candidate species and current threats to their conservation and recovery.

Relevant Information

- The Steller sea lion is the only free ranging federally listed species known to occur on National Forest System lands within the planning area. The western distinct population (DPS) segment of Steller sea lion is designated as an endangered species and has critical habitat designated for two rookeries and seven haul out sites on NFS lands in Prince William Sound.

Current Condition

The following federally listed vertebrate species (see tables 36, 37, and 38) have the potential to occur within the plan area. Because most are exclusive to the marine environment, only the Steller sea lion will receive further evaluation. There are no federally listed or delisted plant species known to occur in the plan area. The only plant federally listed or proposed by the USFWS in Alaska is *Polystichum aleuticum*, which is endangered and only known to occur on Adak Island in the central Aleutian Islands.

Table 36. Endangered species with potential to occur in the plan area

Species	Relevant Range
Aleutian shield fern (*Polystichum aleuticum*) (USFWS, 2012d)	Adak Island, Aleutian Islands
Bowhead whale (*Balaena mysticetus*) (NMFS, 2013a)	Arctic Ocean and adjacent seas
Cook Inlet beluga whale (*Delphinapterus leucas)* (NMFS, 2012a)	Cook Inlet
Blue whale (*Balaenoptera musculus*) (NMFS, 2013b)	Gulf of Alaska, North Pacific Ocean
Fin whale (*Balaenoptera physalus)* (NMFS, 2013c)	Gulf of Alaska, North Pacific Ocean
Humpback whale (*Megaptera novaeangliae)* (NMFS, 2013d)	Gulf of Alaska, North Pacific Ocean
Leatherback sea turtle *(Dermochelys coriacea)* (NMFS, 2013e)	Gulf of Alaska, North Pacific Ocean
North Pacific right whale (*Eubalaena japonica)* (NMFS, 2013f)	Gulf of Alaska, North Pacific Ocean
Sperm whale (*Physeter macrocephalus)* (NMFS, 2013g)	Gulf of Alaska, North Pacific Ocean
Sei whale *(Balaenoptera borealis)* (NMFS, 2012b)	Gulf of Alaska, North Pacific Ocean
Short-tailed albatross *(Phoebastria albatrus)* (NMFS, 2014)	North Pacific Ocean
Steller sea lion (*Eumetopias jubatus*) west of 144 degrees (NMFS, 2008)	Gulf of Alaska, North Pacific Ocean
Western North Pacific gray whale *(Eschrichtius robustus);* (NMFS, 2013h)	Coastal waters North Pacific Ocean

Table 37. Threatened species with potential to occur in the plan area

Species	Relevant Range
Northern sea otter (*Enhydra lutris kenyoni*) (Southwestern Alaska population) (USFWS, 2014c)	Gulf of Alaska, North Pacific Ocean
Wood bison (*Bison bison athabascae*)	Captive herd only

Table 38. Candidate for Listing Species with potential to occur in the plan area

Species	Relevant Range
Yellow-Billed Loon (*Gavia adamsii*) (USFWS, 2014d)	Breeds in arctic tundra lakes, winters in Prince William Sound and southeastern Alaska

Steller sea lion (*Eumetopias jubatus*)

Population and demographics

The U.S. population of Steller sea lions was listed as threatened in compliance with the ESA on April 5, 1990 (55 FR 126451). In 1997, the NMFS recognized two distinct population segments (DPS) of Steller sea lions: the western DPS was reclassified as endangered and the eastern DPS was maintained as a threatened species at that time (62 FR 24345; 62 FR 30772). The Chugach National Forest is within the range of the western DPS. The western DPS declined by 75 percent between 1976 and 1990 and decreased another 40 percent between 1991 and 2000, although the most recent available data suggest that the overall trend for the western DPS, through 2007, is either stable or slightly declining (NMFS, 2008).

Suitable habitat

Female sea lions appear to select places for giving birth (rookeries) that are gently sloping and protected from waves. Females with pups begin dispersing from rookeries to haulouts when the pups are about 2.5 months-of-age. Haulout is the term used to describe terrestrial areas used by adult sea lions during times other than the breeding season and by non-breeding adults and subadults throughout the year. Sites used as rookeries in the breeding season may also be used as haulouts during other times of year. Some haulouts are used year-round while others only on a seasonal basis (NMFS, 2008).

Critical habitat was designated on August 27, 1993, based on the location of terrestrial rookery and haulout sites, spatial extent of foraging trips, and prey availability (58 FR 45269). Currently, NMFS has identified two rookeries and seven haulouts as critical habitat within the Chugach National Forest (50 CFR 226.202). Steller sea lion critical habitat includes a 20 nautical mile buffer that may incorporate specific fishery management measures around all major haulouts and rookeries, as well as a terrestrial zone that extends 3,000 feet inland from the base point of each identified rookery and haulout and an air zone that extends 3,000 feet above the terrestrial zone of each rookery and haulout, measured vertically from sea level.

The 2002 Forest Plan requires Forest Service managers to "design and locate facilities or apply seasonal restrictions on human activities when necessary and appropriate to reduce disturbance in important habitat areas, such as birthing areas, nesting areas and winter ranges," including those identified for the Steller sea lion. All projects must comply with requirements of the ESA, MMPA and their implementing regulations as well as other applicable federal and state laws and Forest Service policy. In addition, the 2002 Forest Plan directs the Forest Service to "manage human activities within 750 feet of any hauled out sea lion or seal on land areas to avoid disturbance."

Predator, competitor, and risk factors

Critical habitat with associated buffer zones and fishery management measures were designed to reduce potential for direct human caused mortality and indirect mortality and injury caused by disturbance, as well as localized competition for Pacific cod and Atka mackerel, important Steller sea lion prey species (NMFS, 2008).

The 2008 threats assessment for the western DPS concluded that threats from Alaska Native subsistence harvest, illegal shooting, entanglement in marine debris, disease, and disturbance from vessel traffic and scientific research were relatively minor (NMFS, 2008) but that a great deal of uncertainty remained about the magnitude and likelihood of competition with fisheries, environmental variability, incidental take by fisheries, toxic substances and predation by killer whales as potential threats to recovery of the western DPS (NMFS, 2008). Of these potential threats to species recovery, most are outside the scope of Forest Service management.

At Risk Species—Potential Species of Conservation Concern

A species of conservation concern (SCC) is a species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur in the plan area and for which the regional forester has determined that the best available scientific information indicates substantial concern about its capability to persist over the long term in the plan area (36 CFR 219.9 (c)). Potential SCC are identified and evaluated here. The regional forester shall identify the SCC for the plan area in coordination with the responsible official following completion of the assessment and during development of the revised plan.

In addition to ensuring presence within the plan area, potential SCC were also evaluated based on their rarity at multiple scales and identified threats to their viability and/or persistence at those scales. These threats were then assessed relative to the plan area and the potential for Forest Service management to affect conservation against those threats. Many species were considered for evaluation, but only a few met sufficient criteria as potential SCC for more in-depth analysis.

An initial group of species evaluated as potential SCCs was developed from a review of 133 plant and animal species with status ranks of G/T 1-2 on the NatureServe ranking system. G1 species are considered Critically Imperiled, At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors, and G2 is considered Imperiled, At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors. The status of intraspecific taxa (subspecies or varieties) is indicated by a T rank following the species' global or G rank. A query of the NatureServe system (NatureServe, 2012) and the Alaska Natural Heritage Program (AKNHP, 2012/2013a) provided updated NatureServe rankings. Most of the critically imperiled or imperiled species on the state list do not occur within the plan area and were not given further consideration. Those that were known to occur within the plan area and for which their capability to persist over the long-term in the plan area was in question were evaluated further. These evaluation forms are part of the project record.

Relevant Information

After evaluating the various lists of at-risk species, the potential species of conservation concern have been narrowed to include two birds and five plants: dusky Canada goose, Kittlitz's murrelet, Aleutian cress (Eschscholtz's little nightmare), sessileleaf scurvygrass, spotted lady's slipper orchid, pale poppy, and Unalaska mist-maid. In coordination with the responsible official, the regional forester will determine the final list of SCC for the plan area following completion of the assessment and during development of the revised plan.

Scientific Information from Agencies and Organizations

Evaluation of information and species data made available by USFWS, ADF&G, AKNHP and other sources provided background for identifying and evaluating potential SCC and their conservation needs. To ensure a thorough consideration of species as potential SCC, species found on other watch lists were also evaluated against the SCC evaluation criteria. For vertebrates, the Checklist of Alaska Birds (Gibson, Gill, Heini, Lang, Tobish, & Withow, 2012), the AKNHP species tracking lists for birds, mammals, reptiles, and amphibians (AKNHP 2012/2013b, c, d) and USFWS Birds of Conservation Concern BCR 5 (USFWS, Birds of Conservation Concern; BCR 5 Northwest Forest Plan Forests (Northern Pacific Forest-U.S. portions only), 2008) were consulted, as well as the Audubon Alaska WatchList 2010 (Kirchhoff & Padula, 2010). The 2006 ADF&G publication, Our Wealth Maintained: A Strategy for Conserving Alaska's Diverse Wildlife and Fish Resources, identified the species of greatest conservation need, which included amphibians and reptiles, marine fish, marine invertebrates, seabirds, marine mammals, terrestrial mammals, landbirds, raptors, terrestrial invertebrates, waterbirds, shorebirds, freshwater fish, and freshwater invertebrates, and was also referenced when developing a species list for further consideration. For plants, the newly updated AKNHP Rare Vascular Plant list was consulted (AKNHP, 2012/2013a); this update was a cooperative venture between the AKNHP and Alaska flora experts from an array of agencies and institutions, including the Forest Service.

Alaska Region Regional Forester's Sensitive Species List

A review of the Regional Forester's Sensitive Species List (USDA, 2009) was also conducted. The list includes 17 plants, 1 lichen, and 5 birds. The Alaska Region updated the sensitive species list in 2009. No fish or mammals were found to warrant designation as a sensitive species at that time. This 2009 update resulted from a thorough analysis of existing information relative to native fish, wildlife and plant distribution, abundance, dispersal capability, population trend, life history and demographics, known distribution, suitability and vulnerability of suitable habitats (Goldstein, Martin, & Stensvold, 2009). Information from this recent update as well as subsequent information was used for evaluation of these species as potential SCC. An evaluation form was prepared for each species considered in 2009 and updated for current sensitive species. These evaluation forms are part of the project record for this assessment. Species were evaluated based on criteria provided in 36 CFR 219.9 and associated Forest Service direction (USDA, 2005).

Vertebrates on the Alaska Region Regional Forester's Sensitive Species List

Queen Charlotte goshawk (*Accipiter gentilis laingi*)
Kittlitz's murrelet (*Brachyramphus brevirostris*)
Black oystercatcher (*Haematopus bachmani*)
Dusky Canada goose (*Branta canadensis occidentalis*)
Aleutian tern (*Sterna aleutica/Onychoprion aleuticus*)

Plants and lichen on the Alaska Region Regional Forester's Sensitive Species List

Aleutian cress (Eschscholtz's little nightmare) (*Aphragmus eschscholtzianus*)
Moosewort fern (*Botrychium tunux*)
Spatulate moonwort fern (*Botrychium spathulatum*)
Moonwort, no common name (*Botrychium yaaxudakeit*)
Edible thistle (*Cirsium edule var. macounii*)
Sessileleaf scurvygrass (*Cochlearia sessilifolia*)
Spotted lady's slipper (*Cypripedium guttatum*)
Mountain lady's slipper (*Cypripedium montanum*)
Large yellow lady's slipper (*Cypripedium parviflorum var. pubescens*)
Calder's loveage (*Ligusticum calderi*)
Lichen, no common name (*Lobaria amplissima*)
Pale poppy (*Papaver alboroseum*)
Alaska rein orchid (*Piperia unalascensis*)
Lesser round-leaved orchid (*Platanthera orbiculata*)
Kruckeberg's swordfern (*Polystichum kruckebergii*)
Unalaska mist-maid (*Romanzoffia unalaschcensis*)
Henderson's checkermallow (*Sidalcea hendersonii*)
Dune tansy (*Tanacetum bipinnatum subsp. huronense*)

At Risk Vertebrates—Potential Species of Conservation Concern

Discussions about vertebrate species and concerns for their ability to persist over the long term that are known to occur in the plan area follow. These species have been identified for consideration as potential SCC.

Dusky Canada goose *(Branta canadensis occidentalis)* G5T3, State Ranking S3B

Population and Demographics

Dusky Canada geese occur within the plan area, are currently (as of September 2012) on the Regional Forester's Sensitive Species list (USDA, 2009), and are ranked red on Audubon Alaska's WatchList (Kirchhoff & Padula, 2010) because of their declining abundance. Dusky Canada geese nest primarily on the Copper River Delta and winter in the Pacific Northwest along with several other sub-species of Canada geese (*Branta canadensis*) and the smaller bodied species of cackling geese (*Branta hutchinsii*). Unlike dusky geese, the abundance of other geese, especially the cackling goose (*B. h. minima*), have increased dramatically on the wintering grounds causing significant economic losses to Oregon and Washington agricultural interests. Washington, Oregon, and Alaska have implemented regulations to allow for an incidental harvest of dusky geese in order to provide for sufficient harvest of the more abundant geese to minimize crop depredation. Subspecies of Canada and cackling geese are difficult to distinguish from one another under hunting conditions, requiring regulations that allow for a small incidental harvest of dusky geese. However, the harvest of dusky geese remains far below levels set by the Pacific Flyway Council due to extensive outreach and education and intensive harvest management programs. The incidental harvest of dusky Canada geese has allowed hunting seasons to remain open for other species, greatly reducing economic losses.

Annual dusky Canada geese productivity on the Copper River Delta is often significantly reduced by predation of adults, nests, and goslings. Since 1984, the Forest Service has partnered with various organizations, including Ducks Unlimited, Washington Department of Wildlife and Fish, Oregon Department of Fish and Wildlife, ADF&G, USFWS, the National Fish and Wildlife Foundation, and others to install artificial nest islands (ANI) to improve reproduction, help balance the age structure to a more normal distribution of young to adults, and to reduce predation of young and adults. The program has been successful in providing consistent annual recruitment into the dusky Canada goose population. Use of ANIs has steadily increased and is predicted to increase in the future. From 1984 to 2012, nest success on artificial islands has averaged 65 percent, nearly twice the rate found at natural sites in the area (USDA, 2012a). The Pacific Flyway Council identifies the ANI as one of the best known tools to maintain populations of this species.

Suitable habitat

Dusky Canada geese winter in nutrient-rich, agricultural cropland where they acquire large fat reserves important in meeting the energy needs of migration and reproduction. Aerial surveys of the Copper River Delta during the spring breeding grounds indicate that dusky Canada geese may be increasing on glacial outwash plain habitats, where historically nests were found in low densities, and decreasing in uplift marsh habitats, where nest densities were medium to high (Eldridge USFWS, unpublished data). Long term sustainability of dusky Canada geese may be dependent upon continued ANI work, but the long term plant succession models (DeVelice, DeLapp, & Wei, 2001a) predict that many of the current ponds will eventually turn into sphagnum moss bogs with continued shrub encroachment.

Predator, competitor, and risk factors

The dusky Canada goose population was overhunted in the 1950s and experienced periodic tidal flooding of nesting sites pre-1964. Following the1964 Great Alaska Earthquake, which uplifted the Copper River

Delta up to 11 feet, much of their saltwater marsh habitat underwent extensive changes due to loss of tidal flooding, increased drainage, and reduced salinity. Succession of vegetation has been increasing in the uplift area, and trees and shrubs are becoming more prominent, making the nesting geese more susceptible to terrestrial and avian predators. Bald eagles have increased on the nesting grounds in response to habitat change and are a primary predator of dusky Canada geese and their eggs, especially in years when their preferred prey of eulachon, a small anadromous fish, are scarce during the nesting period.

Summary

Dusky Canada geese were identified as having potential concerns for viability or distribution within the Chugach National Forest in 2002 and were designated as a management indicator species for monitoring population trends, habitat characteristics, and changes (USDA, 2002b). The Forest Service has not developed standards or guidelines specific to the management of this species, but guidance was provided within the Waterfowl and Shorebird Habitats Management section (USDA, 2002b). The relevant existing information and summary of the status of ecosystem integrity provided previously and more extensively within the project record indicate vulnerability of this species and a concern about the species' capability to persist within the plan area.

Kittlitz's murrelet (*Brachyramphus brevirostris*) G2 S2

Population and demographics

Present-day populations of Kittlitz's murrelet occupy a large range and are geographically clustered, usually in remote areas that are difficult to reach and survey. Many areas of their range have not yet been systematically surveyed or are under-represented by existing survey efforts (USFWS, 2013). Records indicate that Kittlitz's murrelets in Prince William Sound (four percent of rangewide population estimate) had declined by 84 percent between 1989 and 1995, owing in large part to the 1989 Exxon Valdez oil spill (USFWS, 2011b). There is uncertainty regarding the status and trend of Kittlitz's murrelets within Prince William Sound. Since 2000, populations appear to be either stable or declining and are projected to continue to decline at a much slower rate (USFWS, 2013).

Suitable habitat

Kittlitz's murrelets are solitary nesters and most are found in association with tidewater glaciers during the breeding season, but breeding has also been documented throughout their range in areas where glaciers no longer exist. Offshore, Kittlitz's murrelets occur primarily in Alaska state waters (zero to 3 nautical miles (nm) from shore), and within the U.S. Exclusive Economic Zone (3 to 200 nm from shore) in southern and northwestern Alaska. Onshore, this species is found on lands managed by the Forest Service, USFWS, National Park Service, the State of Alaska, Native lands, and Department of Defense lands (USFWS, 2011b). Kittlitz's murrelets are known to nest on lands within the Chugach National Forest. Throughout their range, barren areas, which are characterized by bare rock, gravel, sand, silt, or clay with little or no green vegetation present, appear to be the preferred nesting habitat (USFWS, 2013). The Kittlitz's murrelet disperses nests across the landscape and relies on cryptic coloration and behavior to avoid predator detection. On the mainland in south-coastal Alaska, nunataks appear to be favorable habitats presumably because of their isolation from terrestrial predators (Kissling, unpublished data, 2013). These habitats are not limited to within the Chugach National Forest or typically affected by Forest Service management.

Predator, competitor, and risk factors

The loss of tidewater glaciers is a threat to the species and the magnitude of that threat is high because of the rate of change in the glaciers (USFWS, 2011b). The USFWS identified poor nest success as the underlying reason for the population decline since the oil spill. Petroleum hydrocarbons in marine waters are considered among the most potentially harmful contaminants to marine birds and their prey. The Kittlitz's murrelet is considered highly vulnerable to marine oil pollution because this species spends most of its annual cycle at sea, forages by diving and pursuing prey, and is typically found in areas of greatest potential risk for this hazard.

Summary

The USFWS named the Kittlitz's murrelet as a candidate for protection in compliance with the ESA in 2004. In October 2013, the USFWS published their 12-Month Finding on a Petition to List Kittlitz's murrelet as an endangered or threatened species and found "that listing the Kittlitz's murrelet is not warranted at this time." This finding removed the murrelet from candidate status (Federal Register Vol. 78, No. 192, 2013). Based on the analysis, the USFWS (2013) found "that the stressors are not of sufficient imminence, intensity, or magnitude to indicate that the Kittlitz's murrelet is in danger of extinction (endangered), or likely to become endangered within the foreseeable future (threatened), throughout all of its range," which includes the plan area. Kittlitz's murrelet habitat is not limited to within the Chugach National Forest or typically affected by Forest Service management.

Black oystercatcher *(Haematopus bachmani*) G5 S2S3

Black oystercatchers occur over a broad geographic range. They occupy coastal habitats from the west Aleutian Islands to the east along the coast and coastal islands of Alaska to Morro Bay, California, and on offshore islands to Baja California. Oystercatchers in the plan area nest during the spring and summer and largely migrate from the plan area for wintering (Andres & Falxa, 1995; Gill, Hatch, & Lanctot, 2004; Tessler, Johnson, Andres, Thomas, & Lanctot, 2010). Dominant threats to the species include oil spills and other aquatic pollution, changes in prey as a result of climate change (e.g., ocean pH, increased storm activity), and disturbance (particularly of nesting birds) by human activity on shorelines (largely associated with recreation).

This large shorebird has demonstrated resilience to major ecological disturbance following the Exxon Valdez oil spill. Furthermore, the species demonstrated an ability to disperse into, occupy, and increase in new habitat following the development of open shore habitat on Middleton Island resulting from the 1964 earthquake (Gill, Hatch, & Lanctot, 2004). There is no evidence that significant areas of potential habitat are unoccupied in the plan area or that densities are low relative to the ecological capacity of the species. The most substantial management threat, recreation activities, appear to negatively influence a limited number of birds (Poe, Goldstein, Brown, & Andres, 2009), and this activity largely influences a portion of oystercatcher life history that is not dominant in population growth (Caswell, 1989). Potential changes in ocean conditions associated with climate change represent the threat of greatest concern but the direction and rate of change in conditions that influence the oystercatcher are unclear at this time (IPCC, 2007). Much of the coastal area occupied in the plan area is strongly influenced by glacial input, which will influence the marine response to climate on coasts of the Chugach National Forest and therefore the level of threat (e.g., pH changes), but the direction and intensity of response is unknown.

Summary

This species is migratory, with limited distribution within the plan area. Current population and nesting success within the plan area are based on casual observations. There is currently not enough information to determine status. There are no identified site specific threats to persistence within the plan area. This summary is developed from a more complete evaluation filed in the project record.

Aleutian tern (*Sterna aleutica/Onychoprion aleuticus*) G4 S3B

Until recently, the Aleutian tern was placed in the large genus *Sterna,* which included most terns. In 2006, the American Ornithologists' Union reclassified this species based on genetic sequence comparisons. It is now in the genus *Onychoprion,* which includes three other brown-backed tern species. The Aleutian tern breeds only in Alaska and eastern Siberia. It nests in coastal colonies that are distributed over a wide range. Nesting occurs in a variety of habitats (e.g., islands, shrub-tundra, grass or sedge meadows, and freshwater and coastal marshes). The primary diet consists of small fish, which are caught in a variety of ways. The tern may search for fish from the air and swoop down to pick them from the surface, hover and dive to shallow depths, or sit on the surface and dip. They are skilled fliers and can take insects out of the air while flying.

The world population is between 17,000 and 20,000 individuals. The breeding population estimate for Alaska is 9,500 birds. On the south and east side of Kodiak Island, Aleutian terns have declined from 1,559 individuals in the late 1970s to two birds in 2002. Because terns are known to shift nesting locations between years, trends are difficult to evaluate. Primary causes of mortality and factors that regulate populations are predation, inclement weather during chick rearing, and human disturbance at nesting sites (USFWS, 2006a).

Summary

This species is migratory, with limited distribution within the plan area. Current population and nesting success within the plan area are based on casual observations. There currently is not enough information to determine status. There are no identified site specific threats to persistence within the plan area. This summary is developed from a more complete evaluation filed in the project record.

At Risk Invertebrates—Potential Species of Conservation Concern

Alaska invertebrates with potential concern total 23 species. Evaluations of these species determined that none were known to occur within the Chugach National Forest and most were of limited range occurring well away from the national forest.

At Risk Plants—Potential Species of Conservation Concern

Discussions about plant species and concerns for their ability to persist over the long term that are known to occur in the plan area follow. These species have been identified for consideration as potential SCC.

Aleutian cress (*Aphragmus eschscholtzianus* Andrz. ex DC.) G3, RFSS

Population and demographics

Eschscholtz's little nightmare is distributed from the Aleutians east along the Alaska Range and Wrangell St. Elias Mountains to the southern Yukon and into the Tatschenshini River area of British Columbia. There are 57 known populations scattered over a large geographic area (AKNHP, 2012/2013a). Only one population is known within the Chugach National Forest. It occurs in the upper end of Palmer Creek Valley on the Seward Ranger District (collected by J.A. Calder in 1951). This population was relocated by Forest Service botanists in 2011 during Aleutian cress rare plant surveys.

Suitable habitat

Alpine tundra; on moist, bouldery, solifluction slopes; wet mossy seeps; wet seepage areas among rocks; snow melt areas (University of Alaska, Fairbanks Herbarium Data (ALA)); and fine gravel saturated by snow melt water (Rollins, 1993).

Predator, competitor, and risk factors

The habitat for this plant is fragile and is slow to recover from disturbance. Some of this habitat is being damaged by communications sites, recreation activities, and minerals activities. The known *Aphragmus* populations are located in an area of historic mining activity in the Palmer Creek Valley. The area is identified as Most Favorable, Developable on the mineral potential map (see the map package appendix). Climate change may lead to changes in habitat that could extirpate the plant from the Chugach National Forest (Carlson & Cortes-Burns, 2012).

Summary

A. eschscholtzianus is known from only one area within the Chugach National Forest. Specific threats to the plant in the national forest include potential minerals activity and climate change.

Sessileleaf scurvygrass (*Cochlearia sessilifolia* Rollins) G1G2Q S2Q, RFSS

Population and demographics

Sessileleaf scurvygrass is endemic to south coastal Alaska. It is known from Nuka Bay in Kenai Fjords National Park (Arctos, 2012); Shoup Bay; Valdez tide flats (AKNHP, 2008); and Kodiak and Sitkalidak Islands (Arctos, 2012; Lipkin & Murray, 1997). Twelve populations have been documented globally. Within the Chugach National Forest, it is documented on the east end of Hawkins Island and on the north shore and near the head of Port Fidalgo (AKNHP, 2012/2013a).

The plant is currently recognized as it was originally named in 1941 by Rollins as *C. sessilifolia* (Al-Shehbaz & Koch, 2010). This is a narrow endemic species of south coastal Alaska known from Kodiak and Sitkalidak Islands, eastern Kenai Peninsula, and Prince William Sound. Twelve populations have been documented globally. Approximately half of the known populations are found on private lands. Within the national forest it is documented from the east end of Hawkins Island and on the north shore and near the head of Port Fildago (AKNHP, 2012/2013a). Some question persists as to the appropriate taxonomic rank for this plant; some authors (Hulten, 1968; Welsh, 1974) have considered this plant a variety of the more common *C. groenlandica*, while more recent treatments (Al-Shehbaz & Koch, 2010; Rollins, 1993) maintain species-level rank.

Suitable habitat

The plant grows in low energy estuarine sites, in the intertidal zone, on gravel bars or spits, generally inundated at high tide (Al-Shehbaz & Koch, 2010; Rollins, 1993). Habitat or population connectivity is limited due to separation of low energy estuarine sites. This habitat is naturally distributed as isolated patches with limited opportunity for dispersal among patches. Some local populations may have been extirpated due to sea level changes resulting from earthquakes or during tsunamis.

Predator, competitor, and risk factors

Sessileleaf scurvygrass is rare throughout its range and abundance is low. Populations in high use recreation areas are vulnerable to invasive species, dragging boats across beaches and other ground disturbing actions.

Summary

Al-Shehbaz and Koch (2010) state that this plant is of conservation concern worldwide. Specific threats include damage resulting from potential heavy recreational uses of beaches and sudden sea level changes.

Spotted lady's slipper orchid (*Cypripedium guttatum* Sw.) G5S4

Population and demographics

The spotted lady's slipper is widespread in temperate/boreal Eastern Europe, Asia, across the Aleutians, and through the Alaska Range east to the Yukon and Northwest Territories. Hulten (1943) does not indicate any plants in southern Alaska east of Kodiak Island, yet in 1968, he indicates a site on the Kenai Peninsula, and Sheviak (2002) includes the Kenai Peninsula on the range map in Flora of North America. The Chugach National Forest is at the southern edge of the plant's North American range.

Suitable habitat

Open shrubby areas, open forests, and mixed forb meadows are habitat for this species. The specimen from the Chugach National Forest (Portage area) grew at the edge of a small pond in an open area adjacent to shrubs.

Predator, competitor, and risk factors

A single, small population of less than 10 plants was known in Portage within the Chugach National Forest until it was wiped out with the creation of a gravel pit in 2001. The nearest known population is north of Palmer, about 62 miles (100 kilometers) north of Portage (Arctos, 2012). Potential habitat in the Portage area has been modified by construction projects and construction of gravel pits and roads. Any undocumented populations may be vulnerable to flower pickers and plant collectors, particularly in areas near roads.

Summary

This species is widely distributed outside and north of the Chugach National Forest with no known populations within the national forest boundary.

Pale poppy (*Papaver alboroseum* Hult) G3G4, RFSS

Population and demographics

The pale poppy is distributed from western to southcentral Alaska, into north central British Columbia (E-Flora BC, 2012/2013). There are about 40 element occurrences documented in the AKNHP and Arctos databases (2012), including several locations within the Kenai Peninsula geographic area. Kiger and Murray (1997) indicate that the plant is infrequent at scattered sites within its range and note that the plant is abundant in the Portage Glacier area.

Suitable habitat

The pale poppy requires an open, well-drained habitat created or maintained by occasional disturbances. Human disturbances, such as stabilized road sides, railroad track beds, and old gravel pits, may provide suitable habitat.

Predator, competitor, and risk factors

While some human disturbance may help maintain suitable open habitat, repeated disturbance, as in the Portage Valley, may have affected the plant's ability to reproduce (Charnon, 2007). Habitat suitability analysis suggests minimal change in areas of highly suitable habitat under future climate scenarios (Carlson & Cortes-Burns, 2012). Invasive plants are flourishing in some areas of pale poppy habitat and are shading out the poppies. Some populations are vulnerable to flower pickers and plant collectors.

Summary

This species is widely distributed. Current information does not indicate substantial concern about the species' capability to persist over the long term in the plan area.

Unalaska mist-maid (*Romanzoffia unalaschcensis* Cham.) G3S3S4

Population and demographics

The Unalaska mist-maid is rare across its range, which extends from the eastern Aleutians across the south coast to southeastern Alaska. The Tongass National Forest provides the eastern edge of its range. Twenty-six of the 34 known Alaska occurrences are located from Kodiak Island west to the Aleutians (Arctos, 2012). This plant is extremely rare within the Chugach National Forest, known from only two locations: Cape St. Elias on Kayak Island, and at Hawkins Creek on Hawkins Island.

Suitable habitat

This plant grows in gravelly areas along streams, and on ledges and crevices in rock outcrops, often along the coast.

Predator, competitor, and risk factors

There is a potential decline in the Unalaska mist-maid's habitat quality and quantity due to road construction, hydroelectric projects, minerals activities, stream restoration projects, and fisheries projects.

Summary

This species is widely distributed in Alaska with limited distribution within the plan area. There are no identified site specific threats to persistence within the plan area.

Climate Change

The composition, structure, and function of an ecosystem is a product of species interactions and both biotic and abiotic responses to environmental drivers. Recent and increasing climate change effects represent the most pervasive environmental alteration affecting the Chugach National Forest. Understanding the consequences of current and future climate change within the national forest requires understanding current patterns in the context of the long-term climate trajectory of the region—many ecosystems of the region are still changing in response to ecological development since the last glacial maximum. The climate in southcentral Alaska is warming with an increase in mean temperature of 3 degrees F having been recorded since 1949 and an additional increase of 4 to 8 degrees F projected by 2100 (Stewart, Kunkel, Stevens, Sun, & Walsh, 2013). There is uncertainty about the magnitude but not the direction of temperature changes that may occur in the area.

A Climate Change Vulnerability Assessment is underway in collaboration with multiple agencies and organizations for the broader southcentral Alaska region that includes the Chugach National Forest (Hayward, Colt, McTeague, & Hollingsworth, in prep.). This assessment examines key biophysical features of the region that influence resource management decisions. Some of the findings stated here are the same as will be reported in the Climate Change Vulnerability Assessment.

Relevant Information

Snow and Ice Recent and Anticipated Changes

- Chugach National Forest glaciers are currently losing about 1.45 mi^3 (6 km^3) of ice per year; half of this loss comes from Columbia Glacier.
- During the past decade, almost all glaciers surveyed within the Chugach National Forest have been losing mass, including glaciers that have advancing termini.
- Columbia Glacier will likely retreat another 9.3 miles (15 km) during the next 20 years before stabilizing.
- Climate modeling suggests that significant warming may occur with increased precipitation but decreased snowfall at lower elevations; increased glacial melt and loss of snowpack may occur with less of a spring surge and greater runoff during winter months; and increasing summer season length may occur with some areas that freeze regularly no longer doing so (Fresco, 2012).

Aquatic Ecosystems Recent and Anticipated Changes

- Climate change within the Chugach National Forest and on surrounding lands may increase flood frequency and magnitude, speed glacial recession, and change the timing of peak and low flows.
- Changes in timing and magnitude of freshwater delivery to the Gulf of Alaska may impact coastal circulation as well as biogeochemical fluxes to near shore marine ecosystems and the eastern North Pacific Ocean.
- Impacts from climate change to non-consumptive national forest water resources include affects to timing, locations, and use of recreational activities, such as whitewater rafting, skiing, fishing, and glacier viewing.
- Impacts from climate change to consumptive national forest water resources include changes in the timing and amounts of water available for water storage, silt loads, and hydropower generation.
- Across the Chugach National Forest, the watersheds most vulnerable to significant shifts in hydrologic processes and associated disruption to the ecology of salmon populations were distributed around periphery of Prince William Sound.
- Based on modeling results, the salmon habitat and species distributions will be vulnerable to climate change. During the next 50 years, as the warm water and cold water boundaries change along the

Alaska coastline, the specific habitat suitability for salmon species may dramatically affect the distributions that are currently observed.
- Impacts from climate change to Chugach National Forest riparian and wetland areas could include increased bank erosion due to increased flood frequency and magnitude, changes in water table associated with changes in low flows and glacial snowmelt contribution, increased stream temperatures, and increased fire potential in some locations in the region.

Terrestrial Ecosystems Recent and Anticipated Changes

- Wildlife species richness and functional redundancy is within expectations for a northern geographic region. Much of the habitat retains natural connectivity, which will allow populations to move as habitat conditions change. The intact nature of the systems suggests a high degree of resilience to climate change.
- Migratory species may be challenged by changes in phenology and more frequent extreme weather events. Changes in phenology have occurred in the past that suggest species are resilient to similar changes.
- Aquatic invertebrates will be affected by warmer water temperatures associated with climate change, and the two amphibians that occur within the national forest, the wood frog and boreal toad, may be impacted as they rely on these invertebrates for food.
- Initial modeling suggests that Chugach National Forest vegetation will have variable ecological responses to climate change. Perhaps the least change will be in the temperate coastal rainforests of the Copper River Delta and the Prince William Sound, which are expected to remain as rainforests.
- The richness and diversity of Chugach National Forest native vegetation likely provides a high level of resistance and resilience in response to change.
- Invasive species pose one of the larger long term threats to ecological integrity. Effects of changing climate, increasing levels of disturbance (both natural and human caused), and increasing tourism and population growth make the national forest vulnerable to introduction and expansion of invasive species. There is an opportunity to develop additional standards and guidelines associated with early detection and rapid response to invasive species.
- Climate change may lead to extirpation of the rare *Aphragmus eschscholtzianus* (Aleutian cress) from the national forest. By 2060, no location within the national forest is predicted to provide highly suitable climatic conditions for Aleutian cress, but suitable habitat is likely to occur north of the Chugach National Forest and state-wide distribution may expand.

Snow and Ice

In a statewide report on Alaska glaciers, Arendt et al. (2002) report glacier thinning from 1995 to 2001 was more than twice as fast as that measured on the same glaciers from 1950 to 1995. The authors state that the “losses are nearly double the estimated annual loss from the entire Greenland Ice Sheet during the same time period” and “form the largest glaciological contribution to rising sea level yet measured.”

Extremely high rates of snow accumulation that occur in maritime climate of the Chugach National Forest result in substantial, short-term variability of glacier mass change in the area. Furthermore, increased precipitation rates at high elevations will likely result in increased glacial accumulation in upper regions while glacial melt at lower elevations results in a substantial net loss of glacial mass.

Climate change is likely to affect the role of snow and ice in the landscapes and hydrology of the Chugach National Forest because temperature and precipitation partially determine when, where, and how much snow falls and melts.

On average, snowfall in the region will likely decline most in late autumn (October to November) and at lower elevations; precipitation falling during this period will likely occur more often as rain.

From October to March and between sea level and 1,000 meters, the number of days with snowfall will likely decline substantially from historical rates; precipitation will fall instead as rain.

Compared to the period from 1971 to 2000, results of modeling suggest a decrease in the percentage of the landscape that is snow dominant. Most of this change would occur at lower elevations.

Aquatic Ecosystems—Watersheds

Climate is an important ecological driver for watersheds and water resources. Consequently, climate change will have a strong influence on future watersheds and aquatic ecosystems.

The most significant effects of climate change to watersheds will be anticipated increased temperatures and changes to the amount, timing, and type of precipitation, such as rain and snow. These temperature and precipitation changes may influence the amount and timing of water quantity and water quality.

Impacts to national forest water resources on water quantity from climate change may include glacial recession, changes in the timing and magnitude of flows, such as increased flood frequency and magnitude and the amount and timing of mean, peak and low flows, increase in fire potential in some locations, and conversion of watersheds from glacial and snow-melt dominated to snow-melt dominated and rain dominated (Fresco, 2012; Haufler, Mehl, & Yeats, 2010). Those changes in hydrologic regime will affect timing and magnitude of discharges, may affect glacial outburst floods, and will change contributions of freshwater discharge into the Gulf of Alaska (Neal, Hood, & Smikrud, 2010) potentially affecting ocean productivity and salmon abundances, water quality, and may affect other multiple uses of water resources.

The Climate Change Vulnerability Assessment identified watersheds vulnerable to shifts in their hydrologic regime (e.g., such as snow-pack dominated watersheds shifting to more snow transitional dominated watersheds). Table 39 and map 7, both taken from the Climate Change Vulnerability Assessment, illustrate the extent of change in watershed precipitation regimes and glacial cover illustrated in the assessment. Results of this assessment identify approximately 8.5 percent of national forest watersheds as likely to change within the next 30 to 50 years. These anticipated changes will be shifts from snow-dominated watersheds to transitional snow-dominated watersheds. The majority of the watersheds exhibiting these expected hydrologic regime changes are located along the southern coastline that rings Prince William Sound. Anticipated affects from these hydrologic regime shifts on the hydrograph may include a shift in peak flows from early summer (June and early July) to late spring (May and June) and decreased flows resulting from less snowpack. Additionally, these watersheds will have an increased peak flow in the autumn, which in some cases may be greater than the peak flow in May and June due to a shift in precipitation falling as rain rather than snow. There may also be slightly higher flows throughout the winter than currently exists within these watersheds due to more precipitation falling as rain than snow. Results of the assessment identified that approximately 13 percent of this will occur in the non-glacial clearwater watersheds, 10 percent will occur within the transitional glacial watersheds, and less than 2 percent will occur within the glacial watersheds. Additionally, it is anticipated that some transitional glacial watersheds may have a shift in their hydrographs as their peak mid-summer flows (July and August) and daily diurnal flow pattern diminish with receding glaciers and some glacial watersheds may have increased mid-summer flows (July and August) and diurnal flows as more melt occurs with the receding glaciers and increased temperatures.

Table 39. Classification of 720 watersheds in the assessment region based on glacial cover and snowpack for current conditions (1971 to 2000) and glacial coverage and snowpack projected from a climate scenario for the period of 2030 to 2059

Snowpack Index	Time Period	Glaciers		
		Clearwater	Transitional Glacial	Glacial
Snow dominant	Current	260	74	251
	Future	212	65	247
Transitional snow	Current	113	17	5
	Future	161	26	9
Rain dominant	Current	zero	zero	zero
	Future	Zero	zero	zero

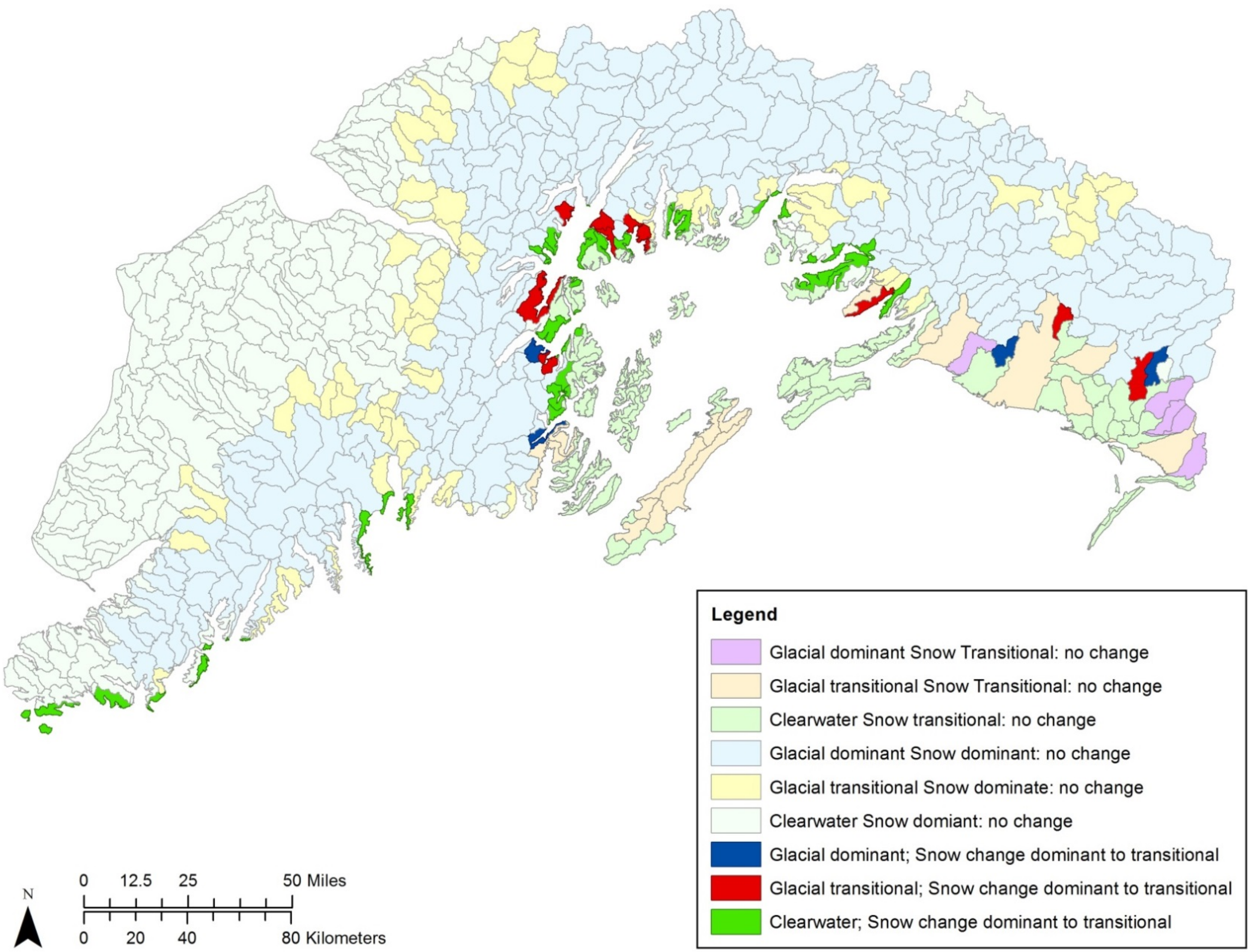
Impacts to national forest water quality from climate change may include increased flood frequency and magnitude leading to increased erosion and heightened turbidity levels from bank erosion, rain-on-snow events and landslides, and increased stream temperatures, and increased erosion and sedimentation from increased fire potential may occur in watersheds on the Kenai Peninsula (Fresco, 2012; Haufler, Mehl, & Yeats, 2010). However, climate change may also improve water quality by lessening turbidity in some watersheds as glaciers retreat.

Aquatic Ecosystems—Fish

Salmon and their associated ecosystems are sensitive to climatic variations and the possible effects are many and complex (Bryant, 2009). Climate change will alter the ecological function with warmer temperatures and changes in stream hydrology in ways that will impact salmon. For example, it is expected that warming water temperatures will accelerate the rate at which salmon eggs develop in gravel and this will result in a timing change for hatching and emergence of young salmon that may be too early relative to the optimum ecological window for survival and growth. To counter this effect salmon will need to genetically adapt to later spawn timing or a slower incubation metabolism. It is also expected that, up to a certain point, warmer ocean temperatures may improve the growth and survival of salmon in this region. In the recent past, periods of colder ocean temperature have been less favorable to survival of Alaska salmon than when ocean temperatures were warmer (Mantua, 2009).

The net effect of climate change on both freshwater and marine systems may cause a shift in the current mix of aquatic ecosystems present within the Chugach National Forest. It may also result in the expansion of certain species that are now relatively uncommon, such as steelhead and cutthroat trout.

It was determined that 61 out of 720 watersheds in southcentral Alaska would be most vulnerable to climate change based on the results of the temperature scenarios modeling in the Climate Change Vulnerability Assessment (see table 39 and map 7) (Hayward, Colt, McTeague, & Hollingsworth, in prep.). In this study, vulnerable is used as an identifier for those places where the changes in hydrologic processes are expected to be the most significant based on modeling results and the potential disruption to salmon populations. Most frequently it represents watersheds where the primary precipitation form was expected to shift from a snow-dominated classification to a snow-rain transition classification. The geographic distribution of these vulnerable watersheds across the study area was non-random, with the majority of these watersheds ringing the mainland shoreline of Prince William Sound.



Map 7. Climate change scenario demonstrating current and future conditions of the planning area using HUC 6 watersheds.

Hayward et al. (in prep) also report the findings from a climate scenario model for pink and chum salmon populations in Prince William Sound. They modeled an overall potential 26 percent increase in the production wild pink salmon during the next 50 years. However, the individual response among the 173 populations modeled was variable and included a number of populations where production levels were projected to decline. There did not appear to be any distinct geographic clusters of populations within Prince William Sound where the projected trends were consistently up or down.

For chum salmon, Hayward et al. (in prep) modeled an overall potential decline of 34 percent during the same time period, although there was a higher degree of uncertainty in this conclusion because the projections for individual populations were highly variable and drawn from a much smaller sample of only 16 populations. Unlike for pink salmon, there appeared to be a pattern among the chum salmon populations with those from the western portion of Prince William Sound projected to decrease in production and those from the eastern portion projected to increase.

Riparian Areas and Wetlands

Impacts to riparian and wetland areas from climate change within the Chugach National Forest could include increased bank erosion due to increased flood frequency and magnitude, changes in water table associated with changes in low flows and glacial snowmelt contribution, increased stream temperatures, and an increased fire potential in some locations (Haufler, Mehl, & Yeats, 2010). Glacial recession may also create new habitats, such as additional wetlands. Increased stream temperatures will likely have an effect on life histories of aquatic invertebrates, which may have a ripple effect through the system that will improve habitat for salmon in some instances and result in poorer habitat in others. Climate change projections for southern coastal Alaska indicate that the area should receive increased precipitation (Fresco, 2012). However, this increase may be offset by the increase in summer temperatures decreasing the precipitation to potential evapotranspiration (P-PET) ratio, particularly on the western Kenai Peninsula. This may result in some wetland drying, an effect that has already been observed on the Kenai Peninsula (Berg, Hillman, Dial, & DeRuwe, 2009; Klein, Berg, & Dial, 2005).

Terrestrial Ecosystem—Vegetation

Changes in vegetation composition and structure have occurred or are occurring within the Chugach National Forest as a result of changing climate. A majority of these changes would be expected based on evaluation of trajectory of the systems as they develop following the last glacial maximum. Under current management practices, there is little direct human influence to the vegetation across about 96 percent of the national forest.

The magnitude of potential effects of climate change on ecosystem composition and structure across the Chugach National Forest is not known. Initial modeling suggests that the national forest will experience variable ecological responses to climate change. Perhaps the least change will be in the temperate coastal rainforests of the Copper River Delta and Prince William Sound, which are expected to remain as rainforests with similar composition and structure.

For the Kenai Peninsula, Dial et al. (2007) reports expansion of shrubland and forest at the boundary between forest and tundra commensurate with recent warming. In addition, Berg et al. (2006) interpret a run of warm summers since 1987 as setting the stage for the large scale infestation of the spruce bark beetle that occurred in the 1990s. As mentioned earlier, since much of the mature spruce on the Kenai Peninsula has already been killed by spruce bark beetle, few acres of further infestation are expected in coming decades due to the limited supply of susceptible host material. However, a changing climate might enable extension of the outbreak into remaining areas of mature, susceptible spruce.

As described by DeVelice et al. (1999), more than 560 vascular plant species have been recorded within the Chugach National Forest, equating to about one-third of the total flora of Alaska. Additionally, more than 280 vegetation community types have been documented. The richness and diversity of native vegetation is likely to provide resistance and resilience in response to environmental change.

One key ecosystem characteristic/current condition that was likely uncommon prior to the development of human caused disturbances (e.g., roads and trails) is the expansion of non-native invasive species. Since invasive species are relatively rare in natural communities within the Chugach National Forest at this time, they likely do not pose an immediate threat to ecological integrity but do pose perhaps one of the larger long term threats if left untended. Climate change could further increase the rates of establishment and spread of invasive plants. In addition, increasing levels of disturbance (both natural and human caused) and increasing tourism and population growth make the national forest vulnerable to expansion of invasive species. Management actions designed to prevent the introduction and spread of invasive species and reducing areas of current infestation are being implemented under the direction of the 2002 Forest Plan and following the national strategy for invasive species (DeVelice, Charnon, Bella, & Shephard, 2005).

Terrestrial Ecosystems—Wildlife

Vertebrates and invertebrates may respond to changing climate and differing phenological patterns in ways difficult to predict (Heintzman & Solomon, 2005). Wildlife responses to predicted changing plant phenology, different predator/prey patterns, drying of some terrestrial communities, changes in ocean pH, variation in insect populations, and new species mixes all could interact to create population and community changes; these changes have not been evaluated. The Chugach National Forest has a diverse flora and fauna and significant ecological redundancy. Much of the habitat has and will retain a high level of natural connectivity, which will allow populations to move to more favorable habitat as climate changes.

The Chugach National Forest supports intact ecosystems of sufficient spatial extent to support ecological functions, such as pollination, seed dispersal, and wildlife movement between patches of habitat. Some migratory species may be challenged by changes to invertebrate phenology if prey abundance peaks before or after migrants visit stopover sites, or if severe weather alters migration. Species that use disjunct areas for winter and summer may be challenged during transitions if the distance between seasonal habitats becomes greater. However, historical ecology demonstrates that migrating species have been exposed to similar climate shifts in the past and persisted through the transition (Wiens, Hayward, Safford, & Giffen, 2012).

Existing species may be affected by invasive species and diseases in ways we cannot anticipate. Similarly, the potential response of birds, amphibians, and other wildlife to rapid climate change is unknown and difficult to assess. In general, however, critical challenges posed by climate change have not been identified for any particular terrestrial animal taxa within the Chugach National Forest for the planning period. Because assessment of the consequences of climate change is ongoing, changes in vegetation, snow, glaciers, and other features will continue to be evaluated for the national forest with an eye toward identifying particular management concerns.

Carbon Sequestration

Barrett (2014) provides information on the storage and change of aboveground carbon in live and dead trees within forest vegetation of the national forest. The Chugach National Forest live tree carbon pool of 26 million tons and its 165 thousand tons per year of net accumulation of live tree carbon is a significant carbon sink. From the first inventory (1999 to 2003) to the second inventory (2004 to 2010), there has been a 4.6 percent increase in carbon mass in live trees within the Chugach National Forest. Mechanisms leading to the increase in live carbon storage are not clear. Climate or the increase in the atmospheric carbon dioxide could be contributing to greater biomass storage or long-term patterns in forests.

At-Risk Species

Alaska, like other northern environments, has lower biodiversity than other geographic areas and therefore, smaller numbers of at-risk species (Flather, Knowles, & Kendall, 1998). Designated threatened, endangered, and candidate species all are tied exclusively to the marine environment except the Steller sea lion. The consequences of climate change on any of these species have not been examined.

Currently seven species are considered potential species of conservation concern: dusky Canada goose, Kittlitz's murrelet, Aleutian cress, sessileleaf scurvygrass, spotted lady's slipper orchid, pale poppy, and Unalaska mist-maid. The potential plant species of conservation concern are being evaluated (to differing extents) in the Climate Change Vulnerability Assessment (Hayward et al. in prep). In a similar effort using habitat suitability modeling, Carlson and Cortes-Burns (2012) estimated distributions for a selection of rare plants in Alaska. Although present elsewhere in Alaska and the Yukon, *Aphragmus eschscholtzianus* (Aleutian cress) is known in only one area within the Chugach National Forest. Climate change may lead to extirpation from the national forest but the species is expected to expand its distribution to the north.

Potential changes in ocean conditions associated with climate change represent a potential threat to black oystercatchers and other at-risk species with strong associations to marine environments, but the direction and rate of change are unclear at this time (IPCC, 2007).

Fire

The majority of wildland fires that occur within the Chugach National Forest take place on the Kenai Peninsula near communities and public concentration areas (e.g., campgrounds) and along roads, trails, and waterways as a result of human activities. With an ever increasing number of people using the national forest, the risk of human-caused fires is expected to increase. The predominance of coastal rainforest on the Chugach National Forest and the low frequency of fire in this system suggest that climate change will have minimal effects on fire within the national forest. Neighboring lands, particularly the western Kenai Peninsula, will likely experience increased fire frequency and intensity.

Cultural Resources

Climate change may cause both harmful and beneficial effects to cultural resources within the Chugach National Forest. Potential harmful effects include damage or destruction to fragile resource sites in coastal areas caused by increased severity of storms and associated storm surges. A potential beneficial effect is that warming may reveal more high elevation cultural resources as ice retreats, thereby increasing knowledge of prehistoric cultures.

Recreation

Literature on potential climate change impacts to tourism and recreation continues to grow (Hamilton & Tol, 2004; Richardson & Loomis, 2004; Shaw & Loomis, 2008), providing a foundation to assess this topic at finer spatial scales or in local settings. The climate assessment currently in preparation will provide some insight into potential effects of climate change. Changes in the portion of the year with snow cover, changes in the number of rainy days, changes in sport-fish abundance, and changes in viewsheds resulting from glacier melt are elements that may influence recreation opportunities and visitor satisfaction. The vulnerability assessment describes expected changes in these elements as a consequence of climate change.

Education and Research

The presence of large expanses of intact ecosystems within the Chugach National Forest provides abundant opportunities to study the effects of climate change on natural systems.

- In May 2013, the Forest Service and the University of Alaska Anchorage co-hosted Classrooms for Climate: A Symposium on the Changing Chugach, Northern Ecosystems, and the Implications for Science & Society. More than 250 participants gathered, bringing together partners in climate inquiry, education, and management. One project that developed from the symposium engages stakeholder communities in a dialogue on their perspectives on the roles and contributions that the Chugach landscape offers in terms of economic, social, and cultural services. Another project evaluates ecosystem services most at risk due to predicted changes in the region's climate, relative to the key economic sectors and socio-cultural systems.
- The Pacific Northwest Research Station, in collaboration with Loyola, Michigan State, Notre Dame and Oregon State universities, was recently awarded a two-year National Fish and Wildlife Federation grant to investigate the effects of climate change on the Copper River Delta.
- Wolverine Glacier is one of three benchmark glaciers studied by USGS and is valued as an indicator of glacial response to climate change (Josberger, Bidlake, March, & O'Neel, 2009) and is within the Wolverine Glacier Research Natural Area (RNA).
- Researchers (Hennon, personal communication, 2013) have been documenting the response of yellow-cedar populations to climate and climate change at Cedar Bay in Prince William Sound.
- Extensive glaciological research is ongoing in the Columbia Glacier-Granite Cove area of Prince William Sound, particularly as it relates to climate change and rapid retreat of the glacier.